Water Power
& INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER
DECEMBER 1961

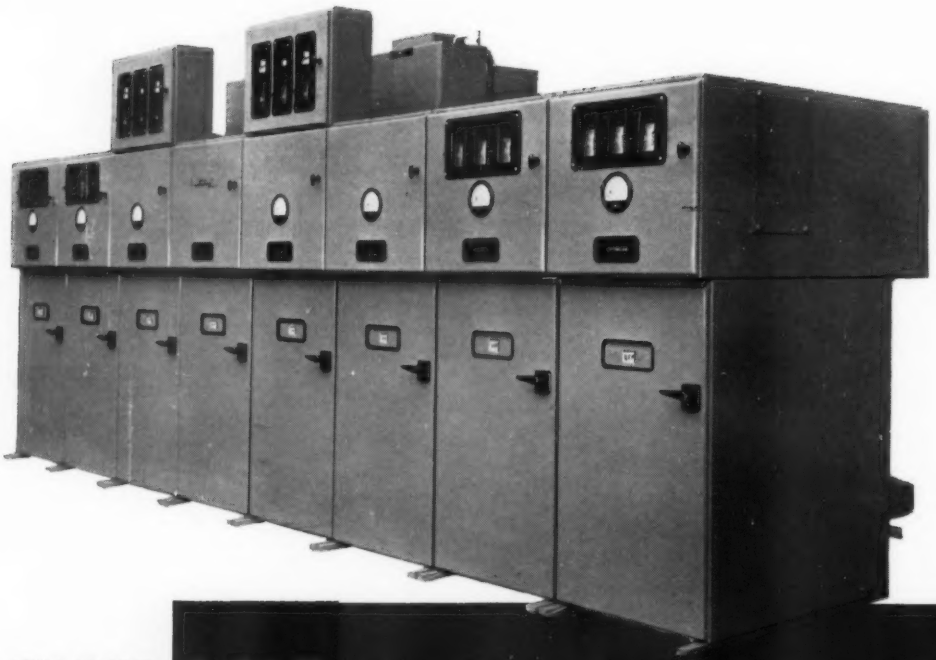
TEXAS ENGINEERS LIBRARY
COLLEGE STATION, TEXAS
DEC 21 1961

One of four 150 MVA 264/132 kV Auto Transformers supplied to the Electricity Supply Commission of South Africa.

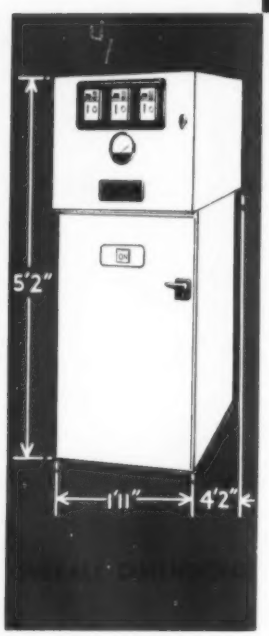
'ENGLISH ELECTRIC'

TRANSFORMER DEPARTMENT, STAFFORD

The English Electric Company Limited, English Electric House, Strand, London, W.C.2



CLASS L M T OIL-BREAK SWITCHGEAR



METAL-ENCLOSED: AIR-INSULATED: VERTICALLY-ISOLATED

Current-ratings: 400, 800, and 1200 amperes.

Design voltages: 11 kV and 15 kV

Maximum operating-voltage 13·8 kV

Breaking-capacity Ratings. 150 MVA at 6·6 kV
250 MVA at 11 kV
250 MVA at 13·8 kV

Independent-manual, spring-operated, or solenoid closing-mechanism.

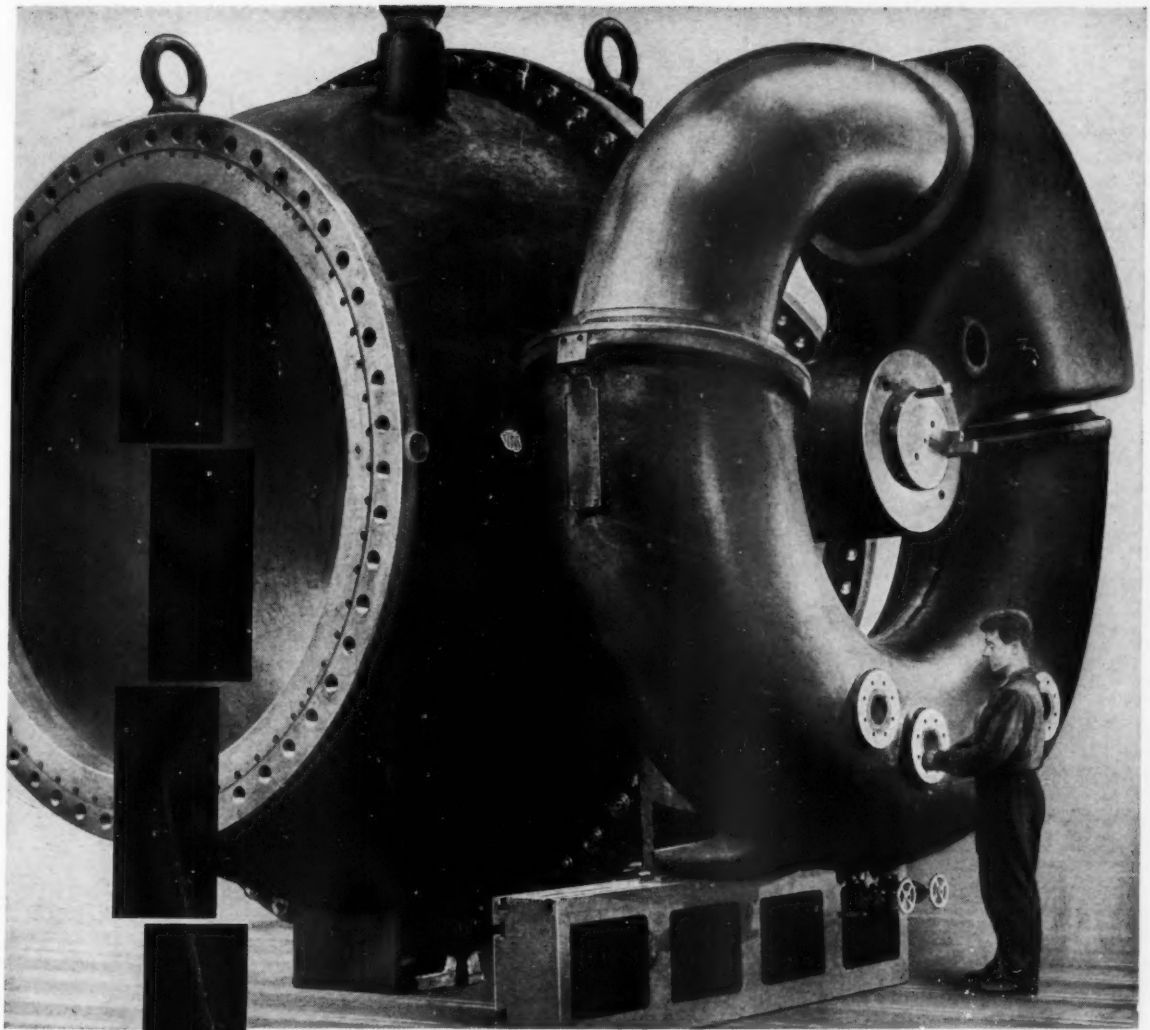
Integral earthing through the circuit-breaker.

Epoxy-resin insulation with PVC-sheathed busbars.

A.S.T.A. certified.

Reyrolle

A. Reyrolle & Company Limited - Hebburn - County Durham - England



Assembly of a Spherical Valve
destined for
Le Marinel Power Station
(Congo)
nominal diameter 2200 mm (87 in.),
working pressure 18 kg/cm² (256 psi),
with patented
Ring-Piston Servomotor

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

323

DE ROLL

Shut-off Valves

our speciality

DE ROLL Iron Works, Klus (Switzerland)

NGK

SOLID CORE INSULATORS

Puncture-Proof Performance

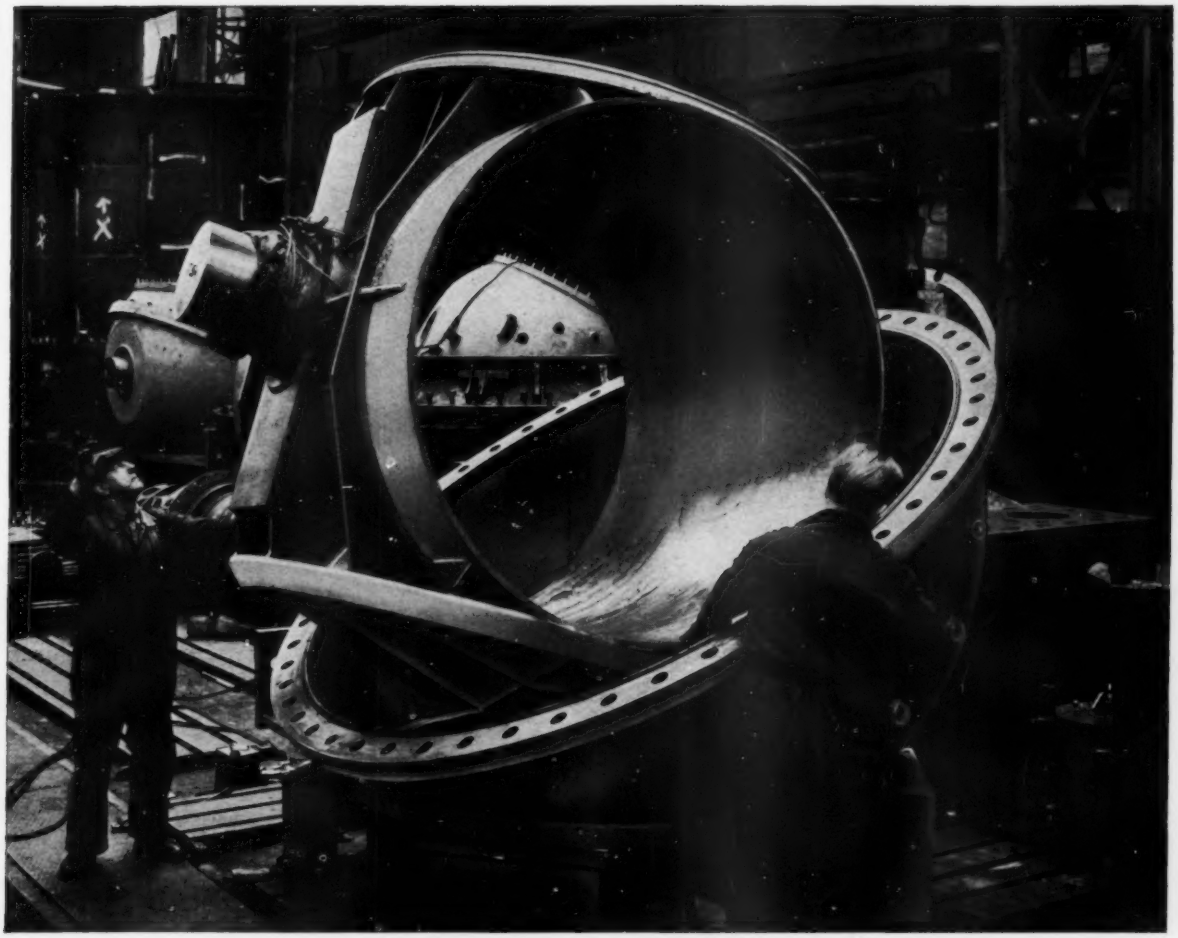
Unlike conventional hollow insulators, which must be protected against moisture seepage with a sealed joint at the bottom, NGK station-post and line-post insulators are of solid-core construction, eliminating moisture seepage and resultant puncture.

This solid-core construction also makes it possible to guarantee a cantilever strength equivalent to that of conventional insulators of much larger diameter. Likewise, the slender body diameter improves anti-pollution performance.

Because of their outstanding qualities of strength, uniformity, and durability, NGK solid-core insulators are gaining in popularity throughout the world.

Cable: INSULATOR NAGOYA. TELEX: NGK-NG9928
Represented in all major territories.

Nippon Gaishi Kaisha LTD.
Mizuho, Nagoya, Japan



Boving robust design ensures

enduring efficiency

The illustration shows Boving Patent Rotary Valves in course of construction. These valves are used in high-head installations and are particularly notable for their –

SIMPLICITY · LOW HEAD LOSS · ROBUST DESIGN

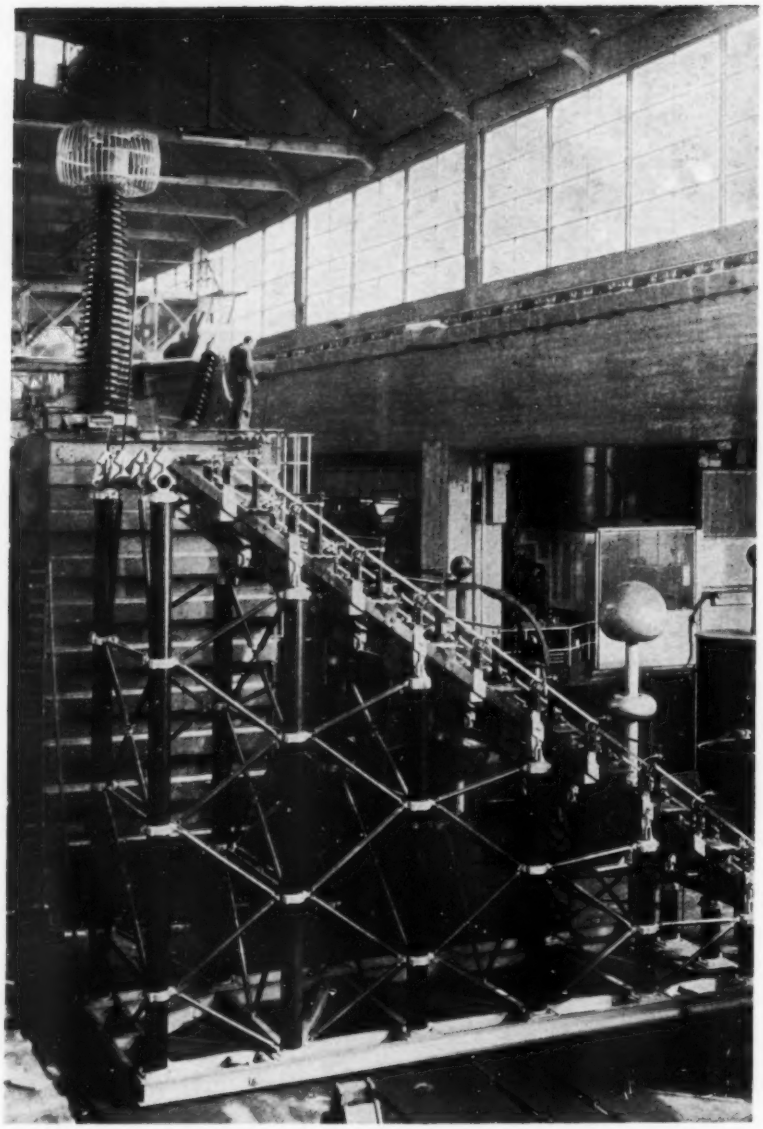
Constant research into design and production methods, backed by the latest advances in technology, maintain Boving Quality at the highest standard. Simplicity and quality finish achieves increased reliability and reduces costly outages.

Boving
A CO LIMITED

VILLIERS HOUSE
41-47 STRAND LONDON WC2

P.4088

A 660,000 kVA 400,000 V TRANSFORMER BANK



A view of one of the four 220,000 kVA-400,000 V single-phase transformers taken during 1.9 million volt impulse wave tests. Three of these units make up a 660,000 kVA three-phase bank, the fourth being held in reserve.

Other ACEC Very High Voltage Equipment

- Shell-type transformers of all ratings and voltages up to 600,000 V
- Reactors up to 600,000 V
- Non-linear resistor lightning arresters for the protection of distribution transformers, HV and VHV networks and large stations.

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Société Anonyme - BELGIUM
Tel. 36.20.20 - Telex : 7.227 ACEC/Charleroi
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ACEC CHARLEROI

LIMITORQUE

push-button valve control saves time and money

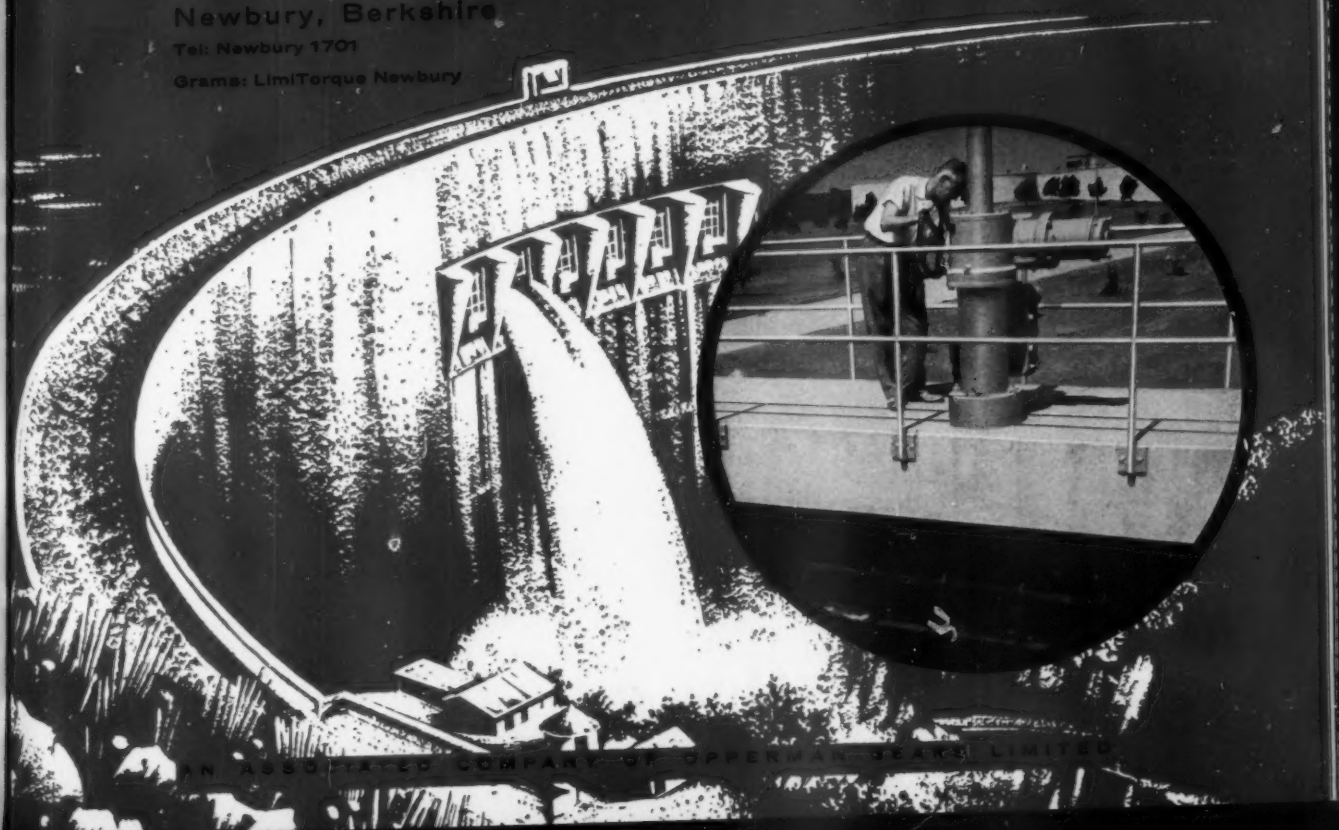
In the hydro-electric industry or wherever large quantities of water have to be controlled, LimiTorque means economy. LimiTorque is the actuator with *fingertip control*. Once it's installed, one man does the work of many—simply, efficiently, with complete dependability. Highly sensitive, and automatic, it can be operated electrically, pneumatically or hydraulically and is easily adapted for use on existing manually operated valves.

LIMITORQUE VALVE CONTROLS LTD

Newbury, Berkshire

Tel: Newbury 1701

Grams: LimiTorque Newbury



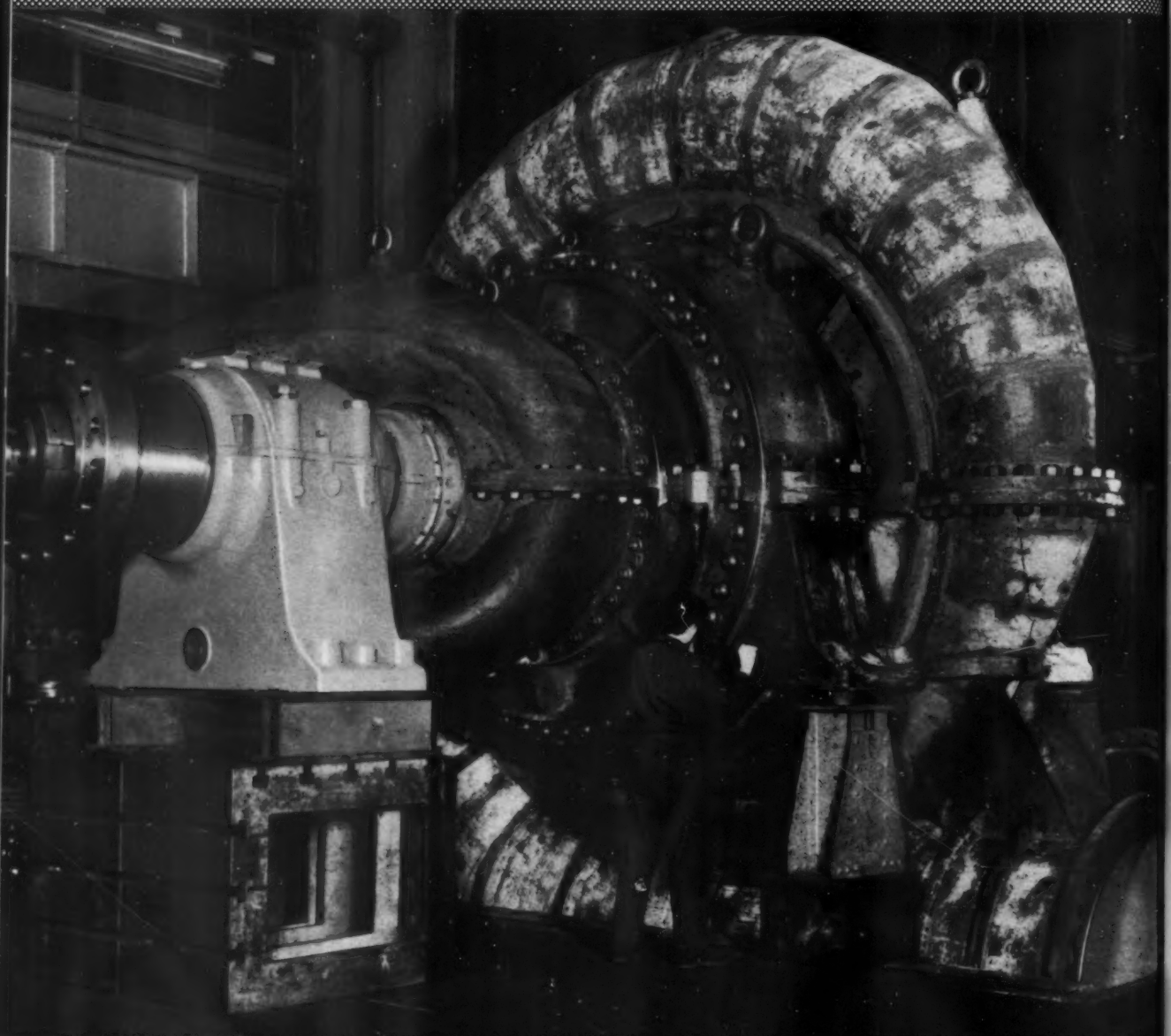
AN ASSOCIATED COMPANY OF [illegible] LIMITED

SOCIETA' GENERALE ELETTRICA DELLA SICILIA

GUADALAMI SCHEME

WE ARE SUPPLYING FOR THIS PROJECT:

- TWO 40,000 h.p. STORAGE PUMPS
- TWO 43,000 h.p. FRANCIS TURBINES
- ONE 31,000 h.p. FRANCIS TURBINE

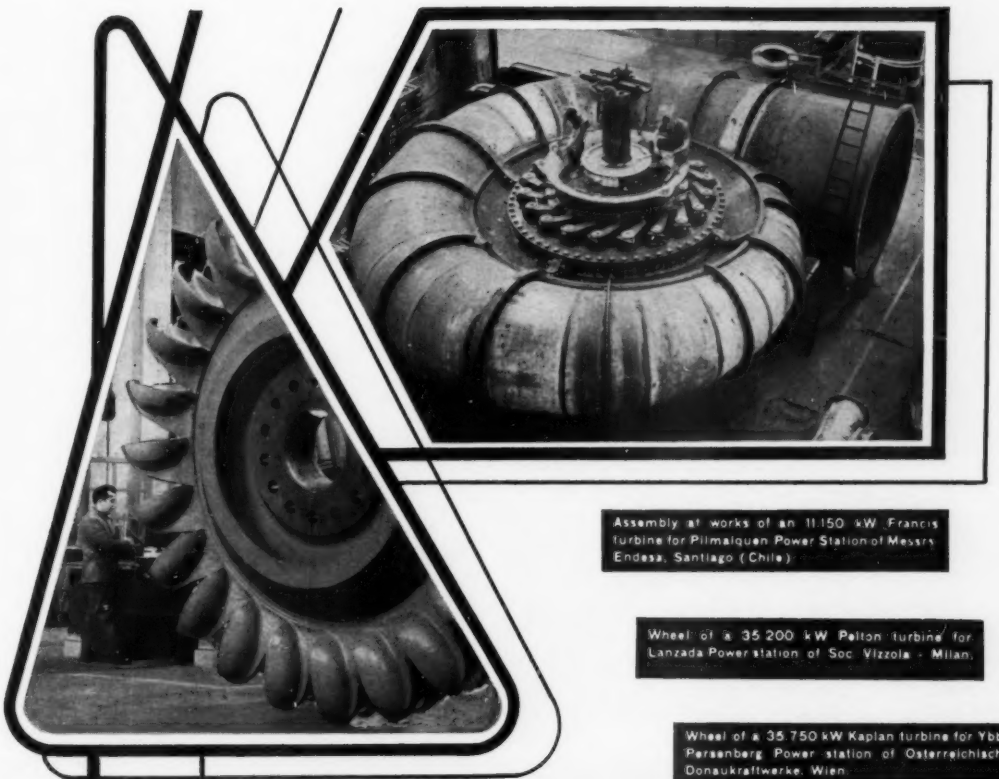


RIVA

COSTRUZIONI MECCANICHE RIVA

VIA STENDHAL 34 MILANO ITALY

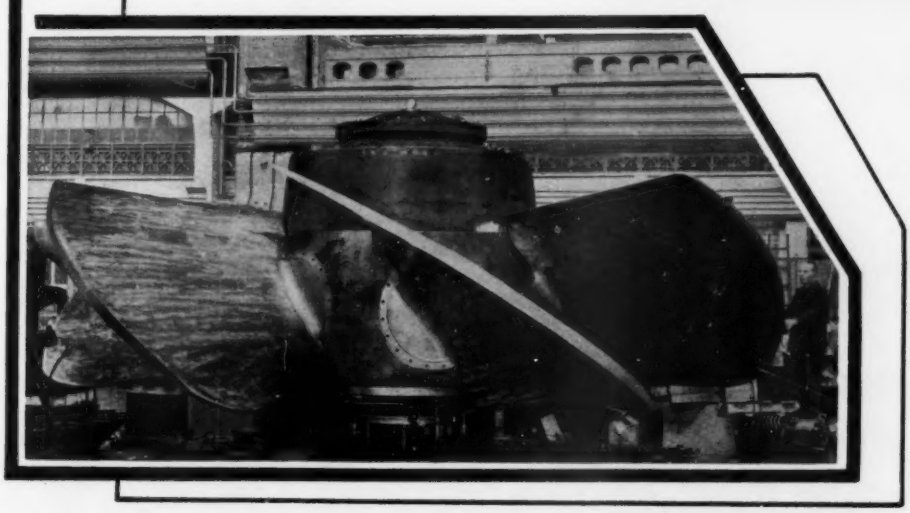
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile).

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

AEI AT THE HEART OF

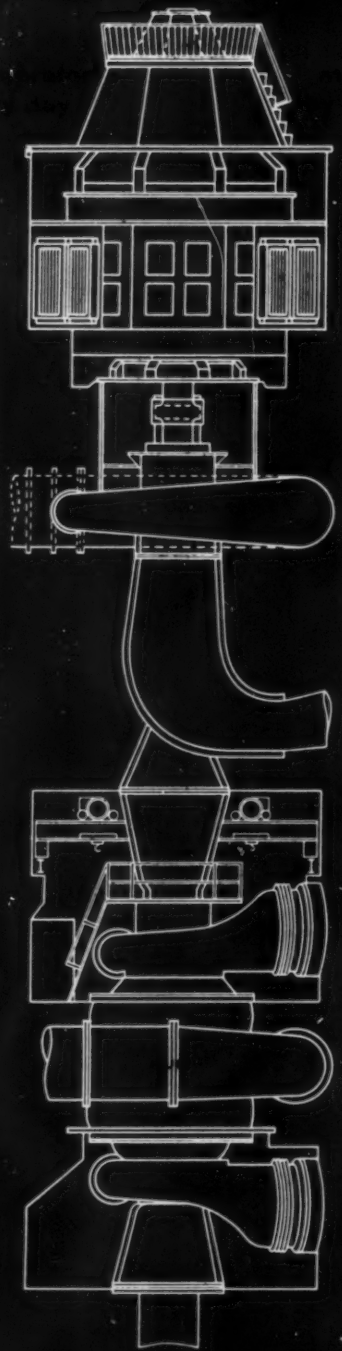
BLAENAU FFESTINIOG

Four 75,000-kW machines supplied by AEI will soon be performing double duty as generators and motors at the C.E.G.B.'s hydro-electric station at Blaenau Ffestiniog, Wales.

By day, water turbines fed from the upper reservoir will drive the AEI machines as generators supplying electricity to the Grid to meet peak loads. After passing through the turbines, the water will be stored in the lower reservoir. At night, when the capacity of the Grid exceeds the demand, the same AEI machines will operate as motors driving pumps to return the stored water to the upper reservoir for further use during the next peak load period.

These dual-purpose machines supplied by AEI Heavy Plant Division are at the very heart of this, Britain's first major pumped storage scheme. In addition, AEI Switchgear Division are supplying the 275-kV motor-driven isolators—which will be used in place of circuit breakers—together with the by-pass isolators, relay and control equipment, feeder protection equipment including control panels, earthing equipment, and multicore cables.

Consulting Engineers: Messrs. Freeman, Fox and Partners and Messrs. Kennedy and Donkin.



AEI

Associated Electrical Industries Limited

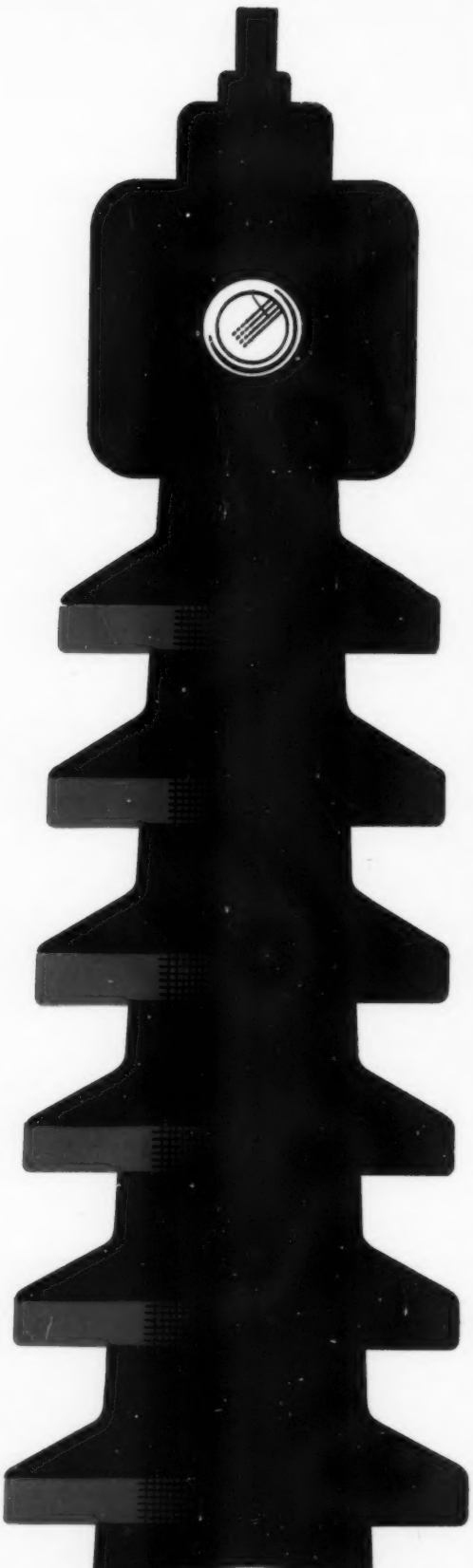
Heavy Plant Division
RUGBY, WARWICKSHIRE
ENGLAND

Switchgear Division
TRAFFORD PARK, MANCHESTER
ENGLAND

m and i

specialise in the manufacture of both indoor and outdoor bushings.

Whatever the voltage rating, M & I supply bushings to meet the requirements of all modern power systems.



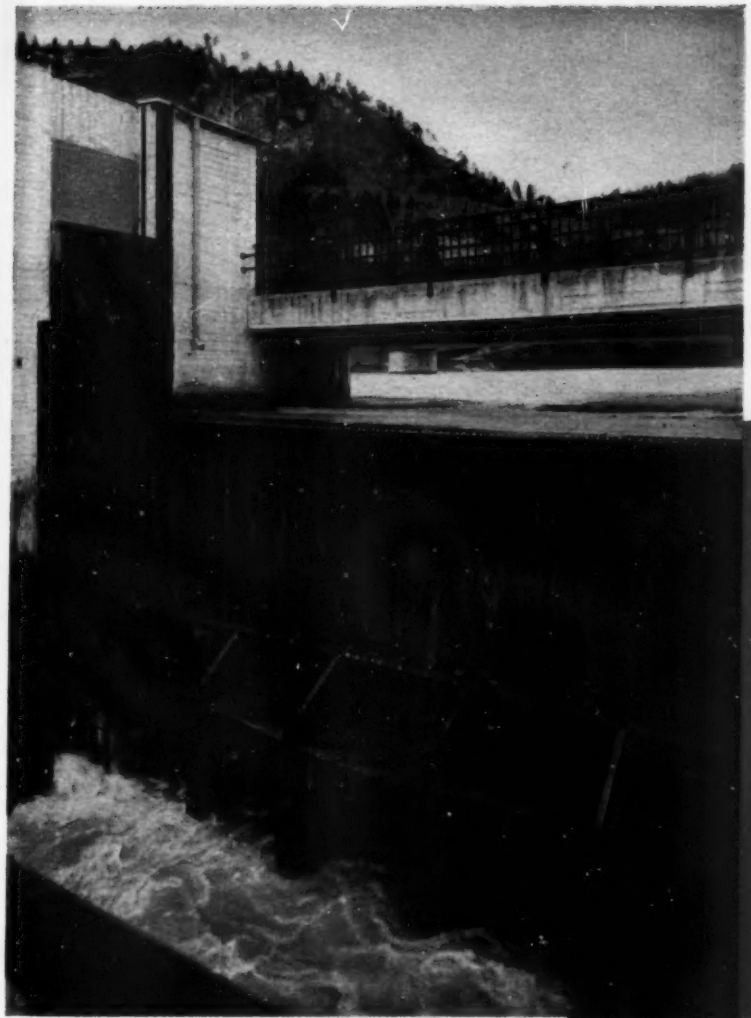
THE MICANITE & INSULATORS CO. LTD.,

WALTHAMSTOW, LONDON E.17.

TEL: LARKSWOOD 5500. 'GRAMS: MYTILITE, LONDON, TELEX.

TELEX: 25183.

M·A·N



HYDRAULIC STRUCTURES

M·A·N hook-type gates enable, besides fine regulation by lowering the top gate by approx. 40% of the total retaining height, the discharge of average floodwater without operating the bottom gate. Füssen/Lech Weir Plant with 3 M·A·N hook-type gates of 10.5 m clear width and 9.0 m retaining height each.

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Constructions électriques SCHNEIDER
Licence WESTINGHOUSE
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Laksapana Power Plant (Ceylon) : Penstocks

Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

Laksapana Power Plant : Two 16,100 kW Pelton units under erection

CONSTRUCTION AND ERECTION OF ANY HYDRAULIC POWER PLANT EQUIPMENT

Penstocks, Valves, Turbines, Alternators, Electric Switchgear, Transformers, etc...

CIVIL ENGINEERING WORK

Another big Hydraulic Turbine and Generator by Hitachi

Switchboard installed at the Miboro Power Station, Central Japan.

Hitachi has recently completed two 137,500 kw/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan.

The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 rpm, a maximum effective head of 200 m and 76.6 cu.m/sec water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7 m and the main shaft a diameter of 95 cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35 m and an outer diameter of 11.2 m.

Since the generator was designed for a rated voltage of 16,500 volts and, in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding.

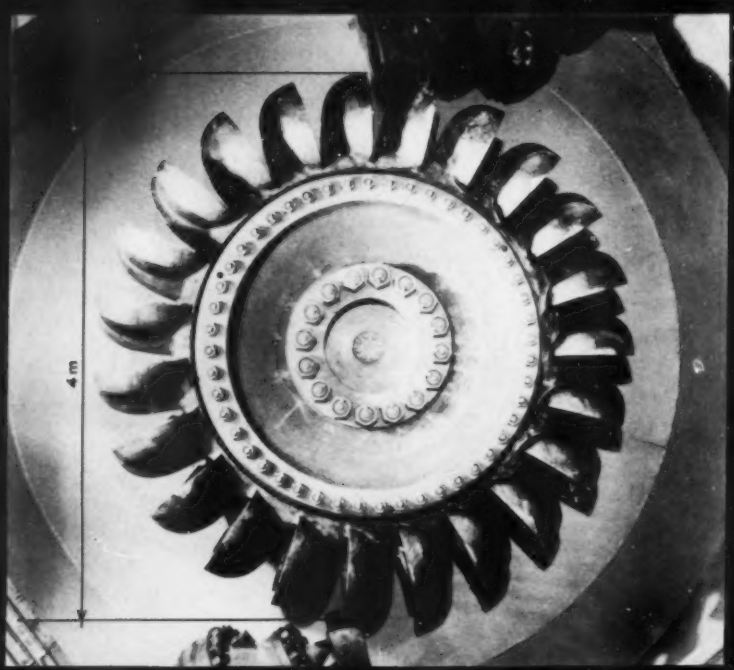
The generator is rated at 60 cycles, 225 rpm and 0.9 power factor but is also capable of operating at 50 cycles, 187.5 rpm and 1.0 power factor.

Hitachi, Ltd.
Tokyo Japan

Cable Address: "HITACHY" TOKYO

Roselend - La Bathie

500 000 kW
from twelve 41750 kW jets
under a 1126 m head



The Roselend plant near Albertville in the French Alps is situated at a height of 1 550 metres above sea level and provides a reserve of some 200 million cubic metres of water for the 500 000 kW power station at La Bathie.

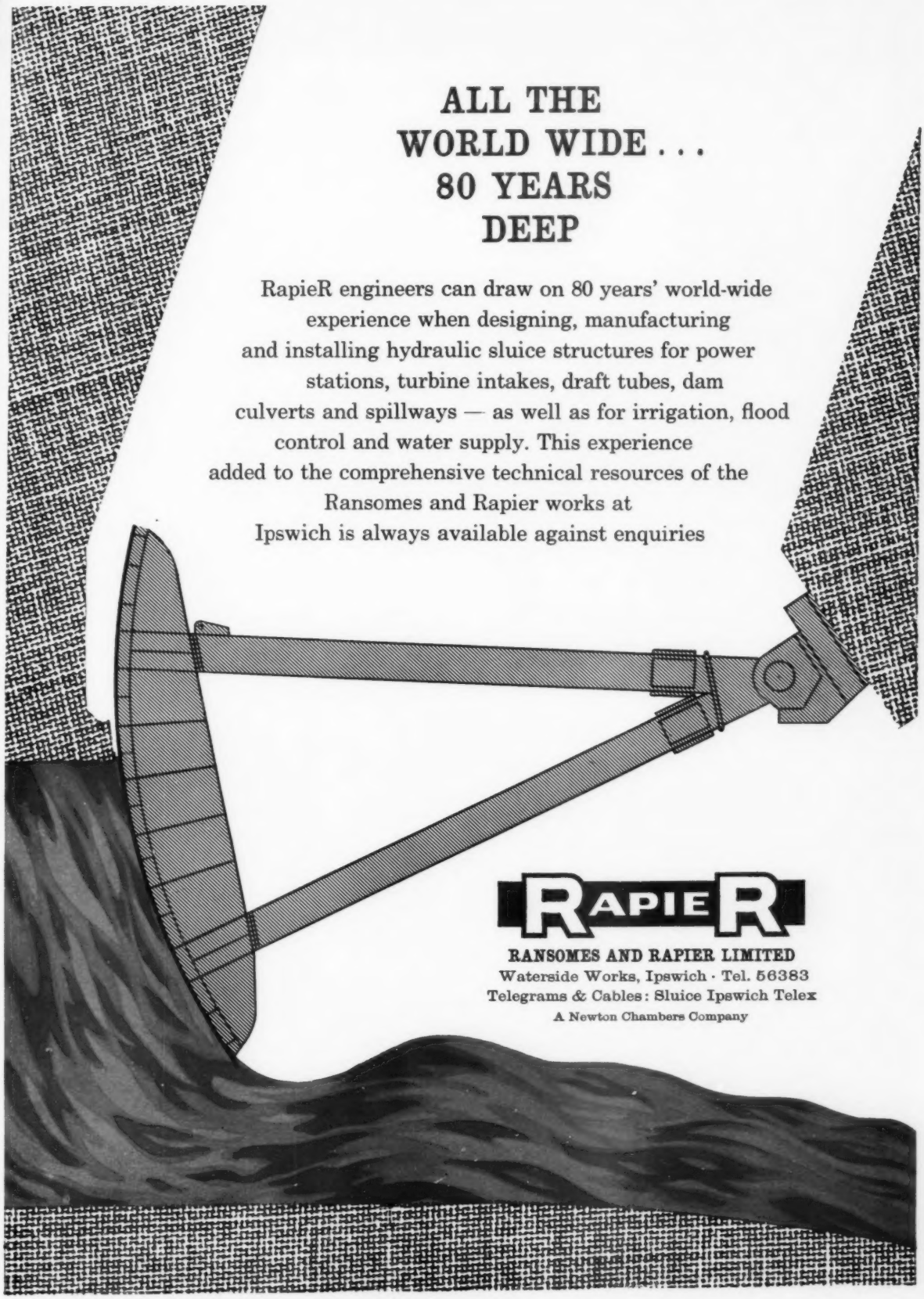
This output is supplied by six 83 500 kW single-runner twin-jet vertical Pelton turbines, each of which is coupled to its own 88 000 kVA alternator running at 428 r.p.m.

The jets discharge from the individual nozzles under a head of 1126 metres at a speed of 550 kilometres per hour, thus each giving an output of 41 750 kW.
All six of these turbines are **NEYRPIC** - built.

NEYRPIC
Avenue de Beauvert
BP 52-Grenoble-France
Tel 44-55-30

ALL THE WORLD WIDE . . . 80 YEARS DEEP

RapieR engineers can draw on 80 years' world-wide experience when designing, manufacturing and installing hydraulic sluice structures for power stations, turbine intakes, draft tubes, dam culverts and spillways — as well as for irrigation, flood control and water supply. This experience added to the comprehensive technical resources of the Ransomes and Rapier works at Ipswich is always available against enquiries



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Kuljian experience in water resources development makes possible the undertaking of every phase of your water utilization project. The Kuljian staff of internationally recognized specialists has supervised the design and construction of many of the world's largest hydroelectric stations, pumping plants and water resources development projects.
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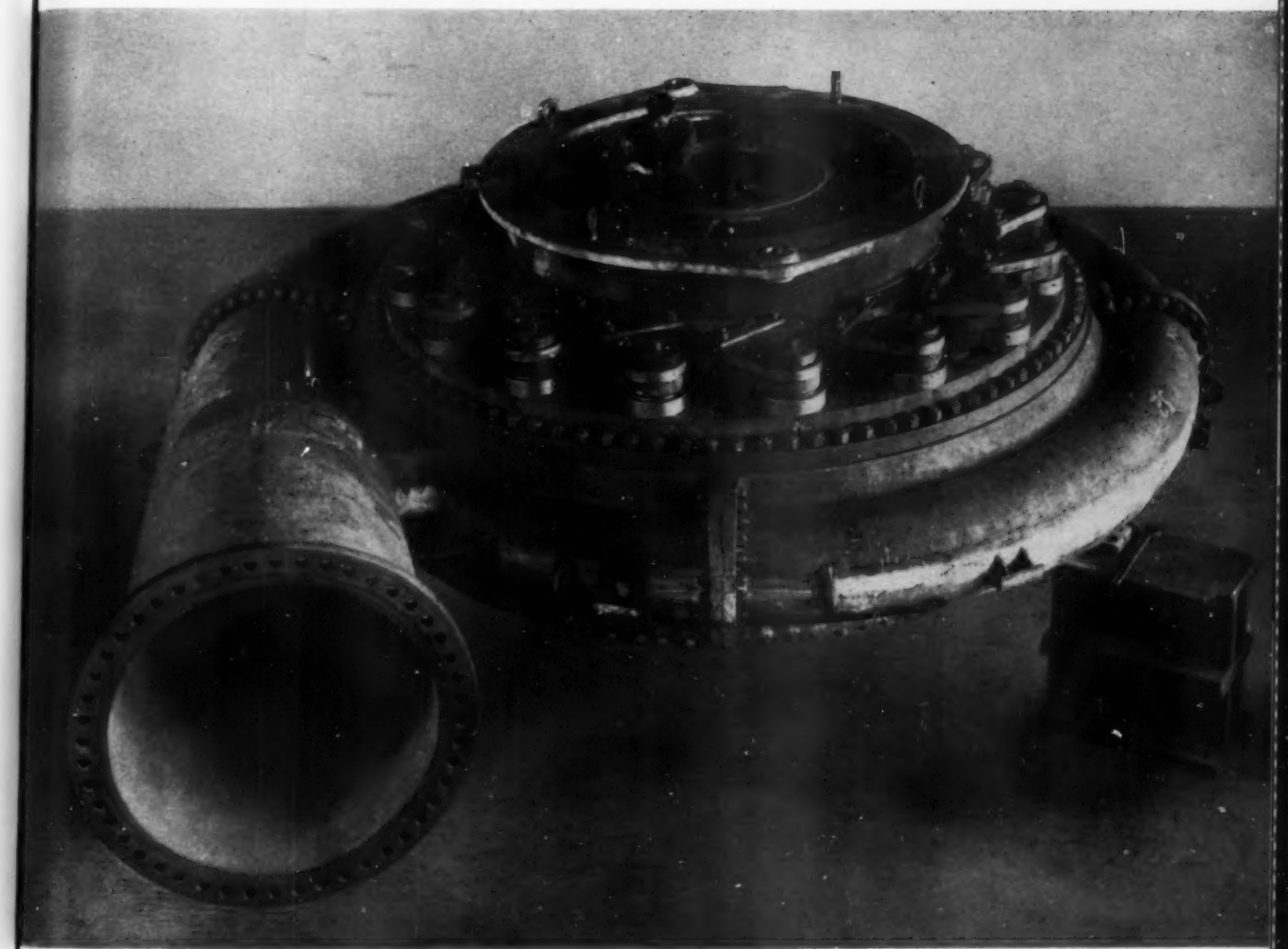

70,000 H.P. Pump-turbine for the Hydro-electric Power Station, Provvidenza (Italy) during shop assembling

TERNI

INDUSTRIAL AND ELECTRICAL COMPANY
STEELWORKS IN TERNI (ITALY)

FORGE FOUNDRY & MECHANICAL DEPARTMENT

SOLE REPRESENTATIVES IN THE UNITED KINGDOM
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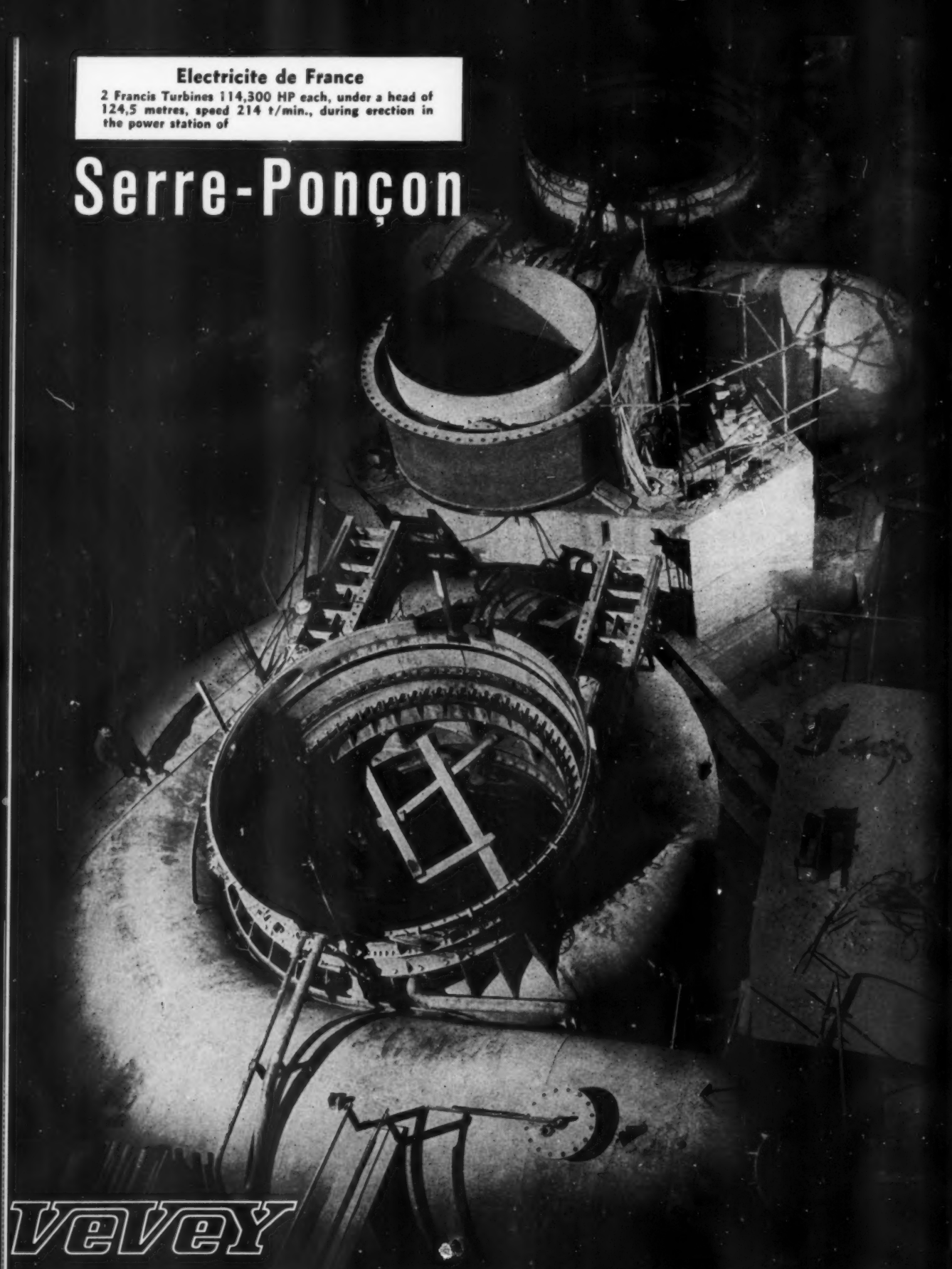
TERNI - S.p.A.
Stabilimenti Siderurgici di Terni (Italia)

Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon

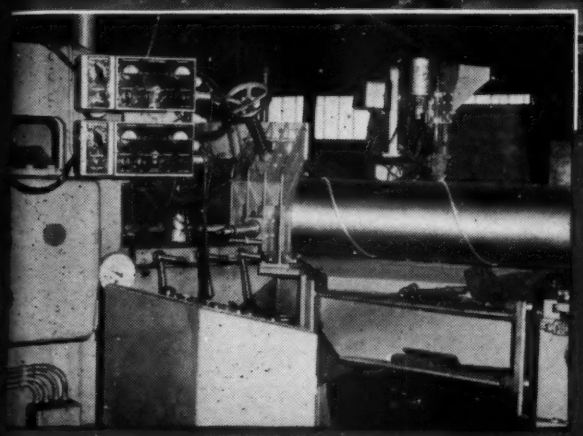


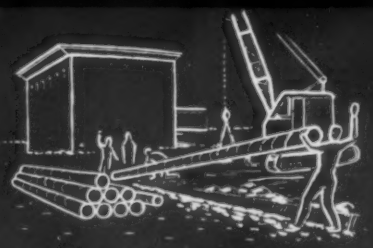
Vevey

Vevey Engineering Works Ltd.

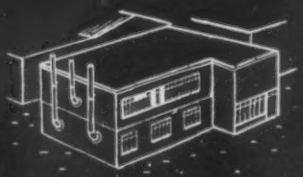
Vevey (Switzerland)

in collaboration with our French licensee:
Cie des Ateliers et Forges de la Loire, St-Chamond (Loire)

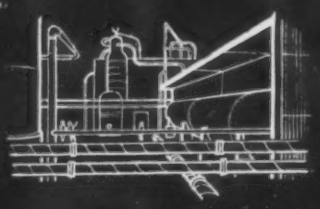




for Water Mains or Gas Mains



for Ventilating Shafts



for Refineries

for Coal Washeries

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Spiracon

SPIRALLY-WELDED STEEL PIPES

Can be made to any reasonable length and in various diameters from 4″ to 12″ for many industrial uses.

SPIRACON Pipe is made at Consett from hot-rolled steel strip, spirally formed and simultaneously welded both inside and out, by the Driam process.

This method of manufacture produces a pipe which is at least 25% stronger than conventional pipe in resistance to internal pressure. The sizes run from 4″ to 12″ internal diameter, with walls of from G14 to ¼″ thickness. Lengths up to 40 feet can be tested hydrostatically for use as water or oil supply lines, but for other uses where there is no internal pressure, such as ventilating shafts and the like, lengths up to 80 or 90 feet can be manufactured. Ends can be cut square or fitted with any standard type of flange.

For further particulars of this new Consett product, with complete range of sizes and test pressures, ask us to send special SPIRACON folder.

CONSETT IRON COMPANY LTD.

CONSETT · COUNTY DURHAM · ENGLAND

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BUILDING FOR POWER

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.

They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

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GATESHEAD-ON-TYNE, 11
Telegrams: Huwood, Gateshead. Telephone: Low Fell 76083. 5 lines.

Industrial and Export Office
ROYAL LONDON HOUSE, FINSBURY SQUARE, LONDON, E.C.2.
Telegrams: Huwood Stock, London. Telephone: Monarch 3273 (4 lines).

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PALAZZOLO HYDRO-ELECTRIC PROJECT

ON THE RIVER OGLIO

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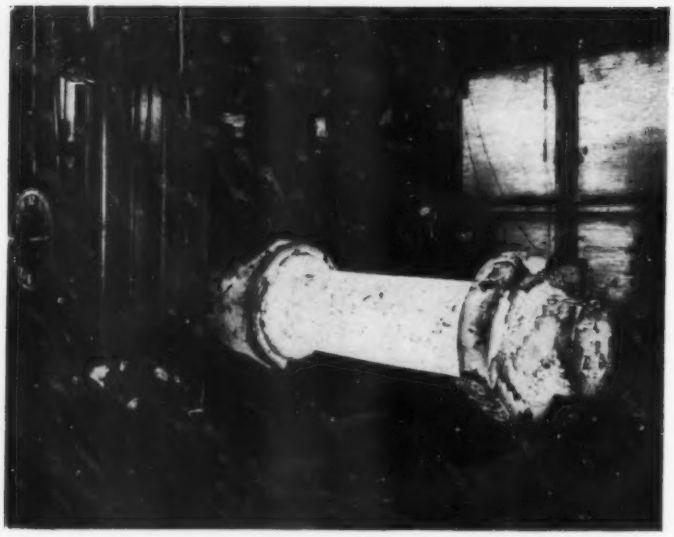
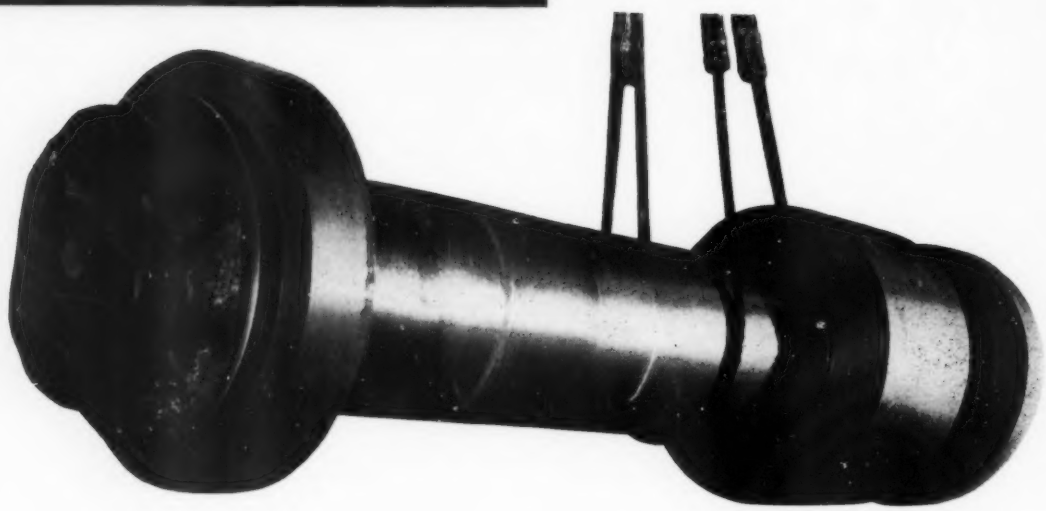


For many years ESC has been the leading supplier of steel forgings to many vital industries. Forgings in weights up to 175 tons are manufactured in our high quality carbon and alloy steels—single piece engineering units produced from ingots weighing up to 300 tons—and



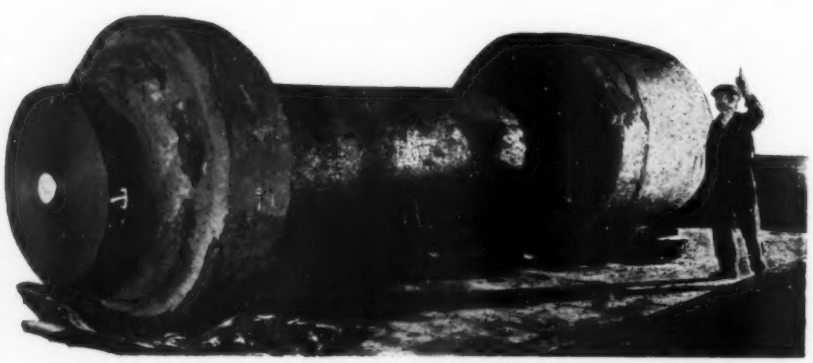
other forgings from ingots 30 cwt. and upwards—for all branches of engineering

ENGLISH STEEL FORGE AND ENGINEERING CORPORATION LTD.

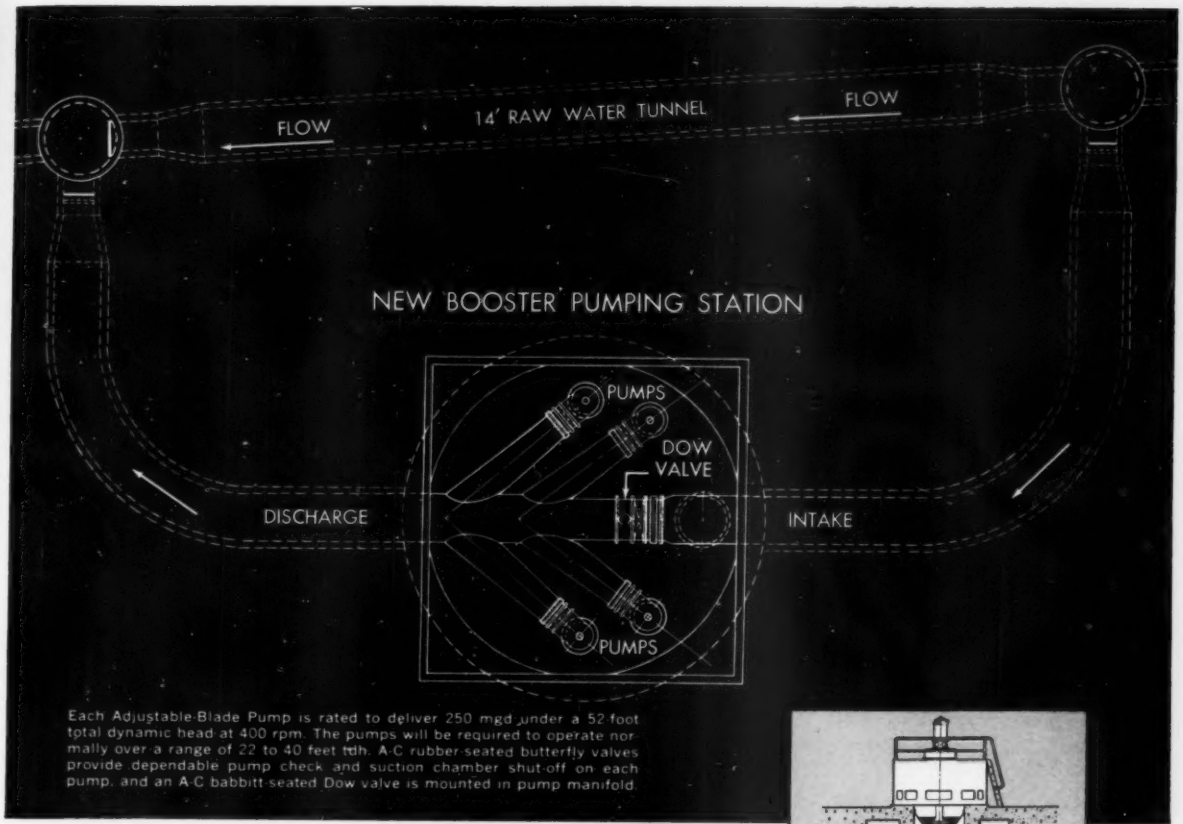
River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd.

Illustrations show a forging operation under an 8,000 ton electro-hydraulic press, rough machined and black forged steel Turbine shafts, 22' 11" long. 3' 8" diameter with 6' 2" and 6' 4" diameter couplings— Weight as forged 111½ tons. rough machined 70 tons—for a modern hydro-electric power project.



ALLIS-CHALMERS



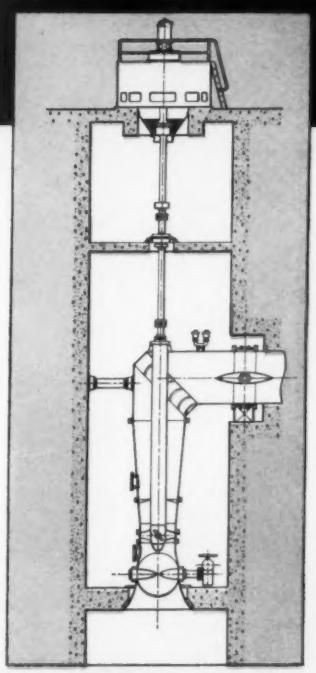
Each Adjustable-Blade Pump is rated to deliver 250 mgd under a 52 foot total dynamic head at 400 rpm. The pumps will be required to operate normally over a range of 22 to 40 feet tdh. A-C rubber-seated butterfly valves provide dependable pump check and suction chamber shut-off on each pump, and an A-C babbitt-seated Dow valve is mounted in pump manifold.

A-C Adjustable-Blade Pumps help City of Detroit augment raw water supply!

To augment the supply of raw water, Detroit, Michigan has installed four A-C Adjustable-Blade Pumps in a new booster pumping plant near the Detroit River. Pumps of this type were selected for their rapid, smooth response, under automatic control, to a wide range of flow demands.

Adjustable-Blade Pumps will vary in output to meet the gradual changes in flow requirement as compared to stepped increments of flow and possible surges which would result if fixed-blade pumps had been installed.

Two of these pumps will operate when required to raise the hydraulic grade line and supply adequate raw water to two remotely located treatment stations. As demand increases, a third pump will be used. A fourth pump is available for standby service. Pump blade angles are controlled automatically by a positioner responsive to downstream hydraulic grade line. A-1488



You may obtain full information on A-C Adjustable and Fixed-Blade High Capacity Axial Flow Pumps and Valves by writing to Allis-Chalmers, Hydraulic Division, York, Pennsylvania.

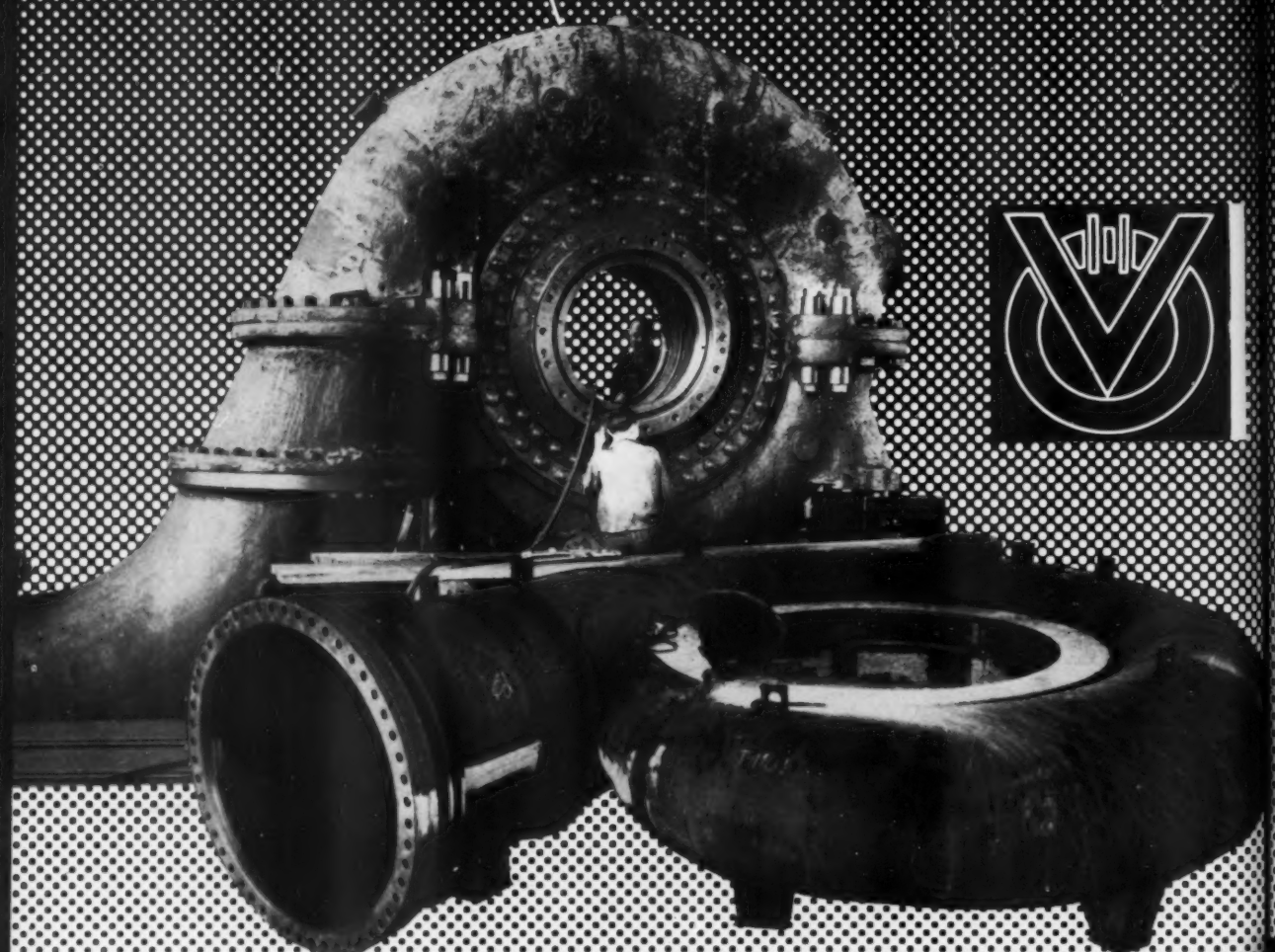
Outside United States contact Allis-Chalmers International, or in Canada, contact Canadian Allis-Chalmers

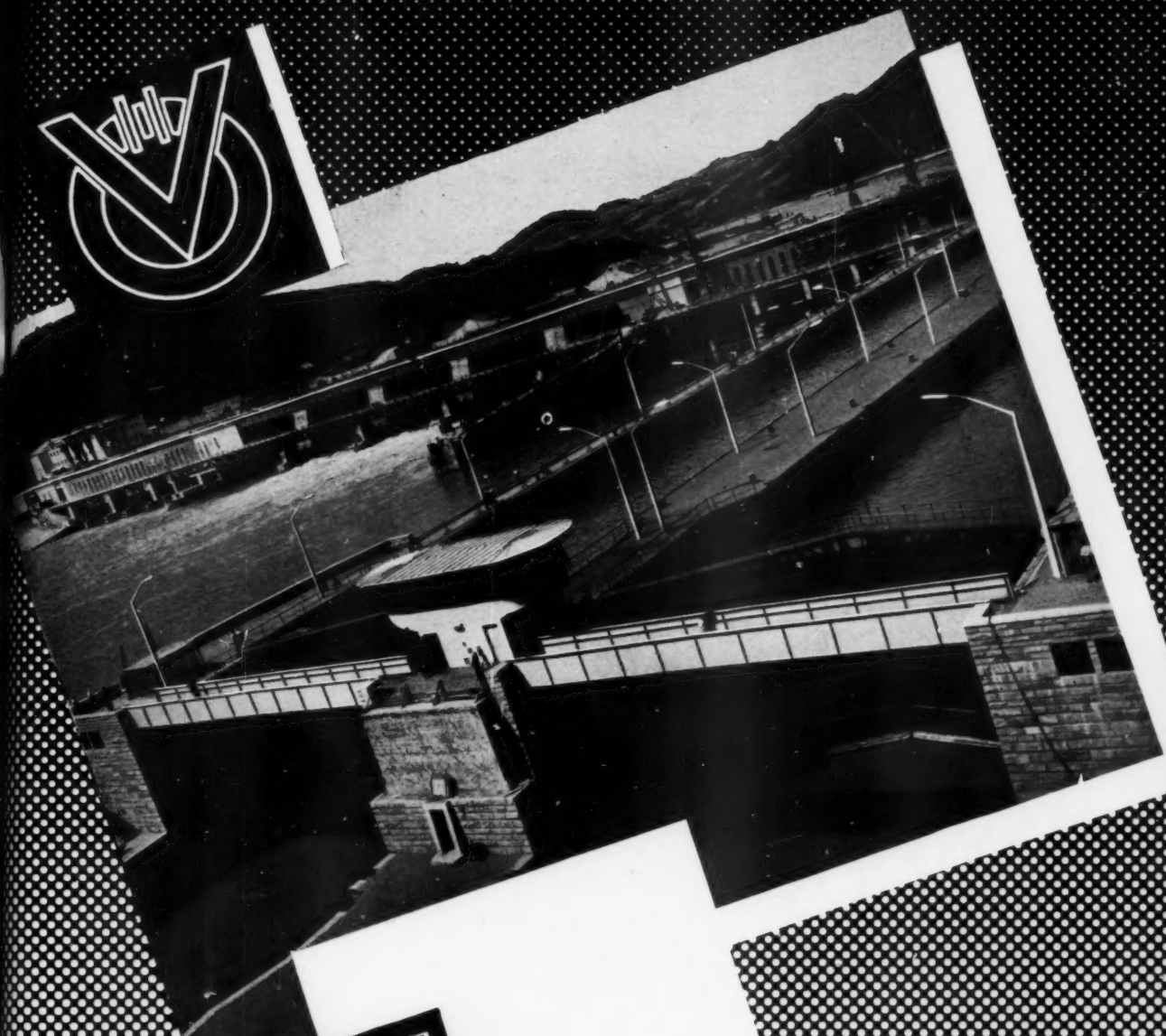
VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

VÖEST

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.





VÖEST

HYDRAULIC
STEEL CONSTRUCTION

Steel structures for weirs and loch gates of every type, including the required auxiliary equipment; mechanical and hydraulic drives hereto sprocket chains; trash rake cleaning machines; weir cranes.

VEREINIGTE ÖSTERR. EISEN- UND STAHLWERKE, LINZ-DONAU

Photograph by P.R. Dept., Uganda Protectorate

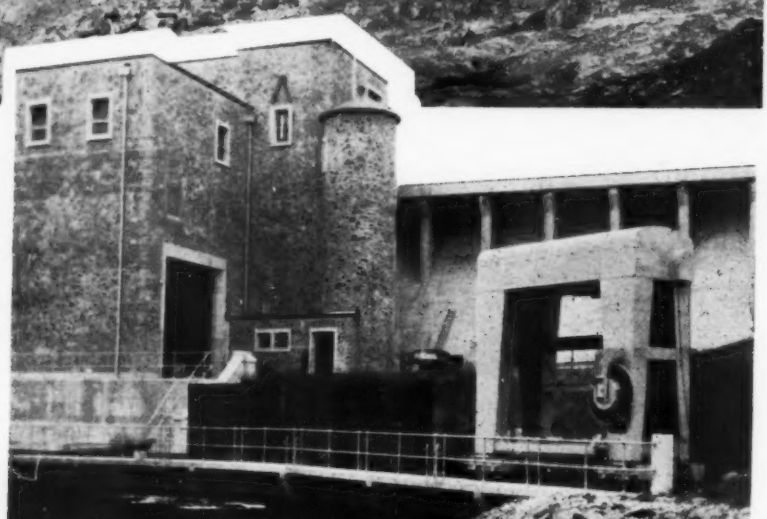
GATES

for

TURBINE INTAKES

and

DRAFT TUBES



Glenfield Gates are employed at the turbine intakes and in the draft tubes of numerous hydro-electric plants in various parts of the world, to effect efficient and reliable flow control. The illustrations show turbine intake gates being installed in a large project in Africa, and draft tube gates in service at a station in Scotland.

Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

Head Office & Works · KILMARNOCK, SCOTLAND

A girl in a million

This Swedish blonde is framed by a million contact springs. Although we have only managed to get about 5000 into the picture, there are actually a million of these springs in the crossbar switches and relays which go to make up a medium-sized automatic telephone exchange. The smooth running of the entire exchange is dependent on the operation of each and every spring. Serious breakdowns in telephone traffic would result if just one spring failed its task. That is why reliability and long life have acquired such urgent importance for the L. M. Ericsson Telephone Company. But first-rate products require first-rate raw materials. Among the materials we supply is nickel-silver plate for contact springs. These springs must never tire and, in fact, they never do — a great number of them have to perform as many as 300 million contact operations during the service life of an exchange. If you place equally heavy demands on your products, perhaps we can help you, too.

POWER LINE BUILDERS BENEFIT TOO

Most of the machinery at Svenska Metallverken's Feral Cable department has been designed specifically for the metals in question — in this case aluminium. Here automatic devices help production and offset human failings. Coils of wire rod are welded together before drawing. Large wirebars mean longer rod coils and fewer welds — and even before being coiled, an electronic device has detected any defects in the rod. Then again, there is an automatic device for stopping the machines as soon as a predetermined length of wire has been spooled into the reels of the standing machines — where it finally becomes Feral Cable, reliable Swedish ACSR.

Push-button operated continuous rod mill at Svenska Metallverken's Feral Cable department.

SVENSKA METALLVERKEN

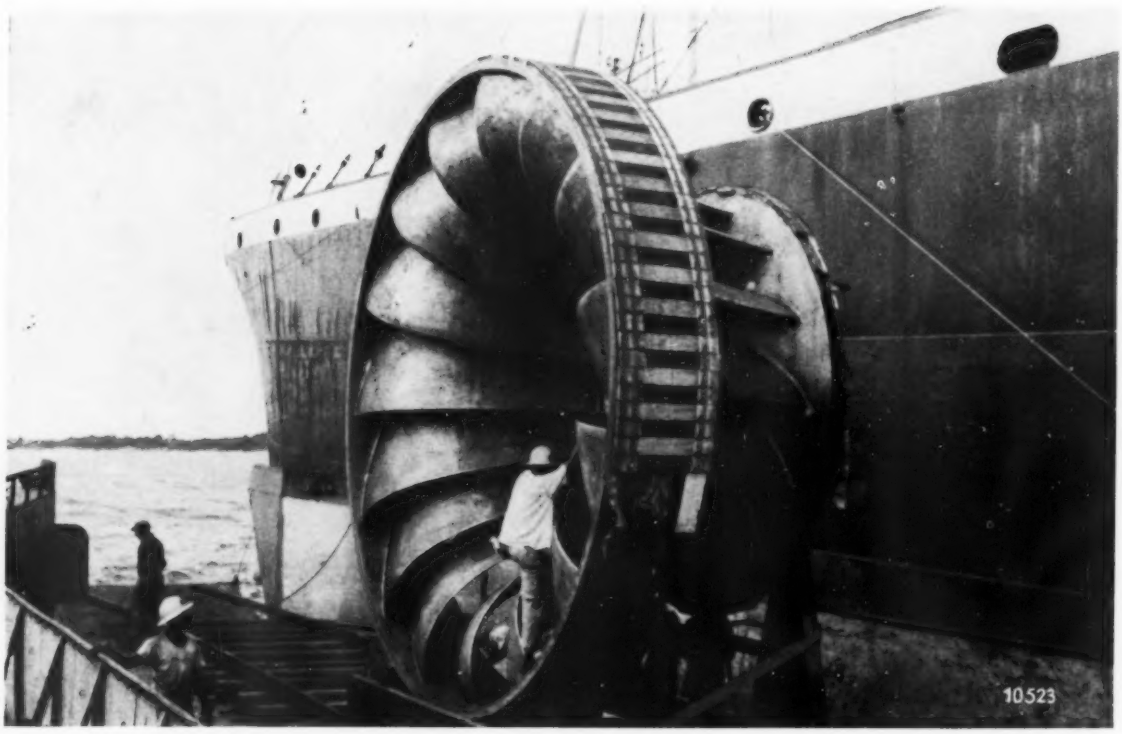
EXPORT DIVISION • VÄSTERÅS • SWEDEN

SUECIA

MANUFACTURERS OF

FERAL CABLE A.C.S.R

VOITH

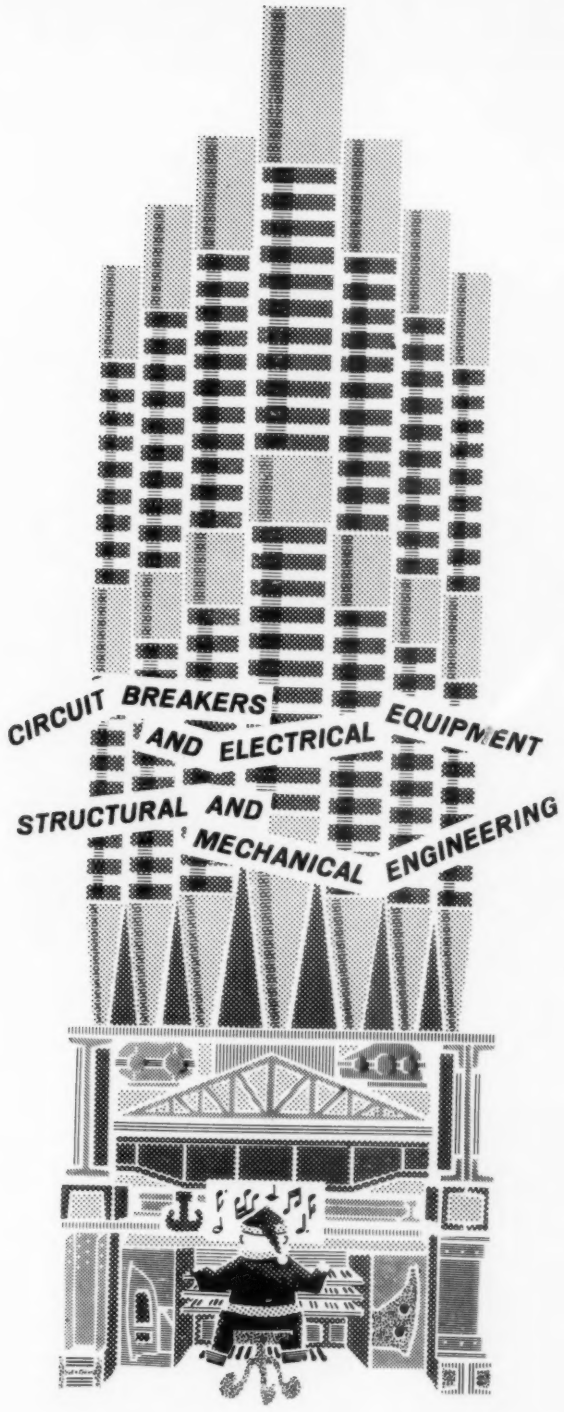


Transport of one of the Macagua Francis runners

Macagua

Macagua Hydro-electric Power Station in Venezuela: By the end of 1961 six machine sets, each rated to develop about 90,000 HP, will be ready for operation.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY



Happy New Year to everybody from

OFFICINE ELETTROMECCANICHE GALILEO
di Battaglia Terme (Italy)

Compound pressure gauges

with zero adjustment

These Bourdon-type gauges, now being supplied by Cockburns, are exceptionally accurate, robust, reliable and keenly priced. Their design has been proved by extensive use in chemical, petroleum, refrigeration and marine industries throughout the world.

The preliminary-pressure and fluctuation shock inaccuracies common to gauges with needle-stops are completely obviated in the compound design. The zero adjustment ensures complete accuracy over the whole scale, at all times, without recalibration.

Standard gauges are available for all pressures, graduated in lbs./in.^{2} or kg./cm^2. A super quality gauge with heavy duty rotary movement designed in association with leading Oil Engineers is also available. Gauges with special corrosion or wear-resistant internals can be supplied.

Other units included in the range of Cockburns Measuring and Controlling Instruments are:-

DIAL THERMOMETERS
mercury in steel, vertical and angled models.

AUTOMATIC SAMPLING UNITS
for regular draw-off of liquid samples.

TEMPERATURE INDICATING CONTROLLERS
for oil tank heating systems.

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A new standard of Accuracy, Robustness and Reliability

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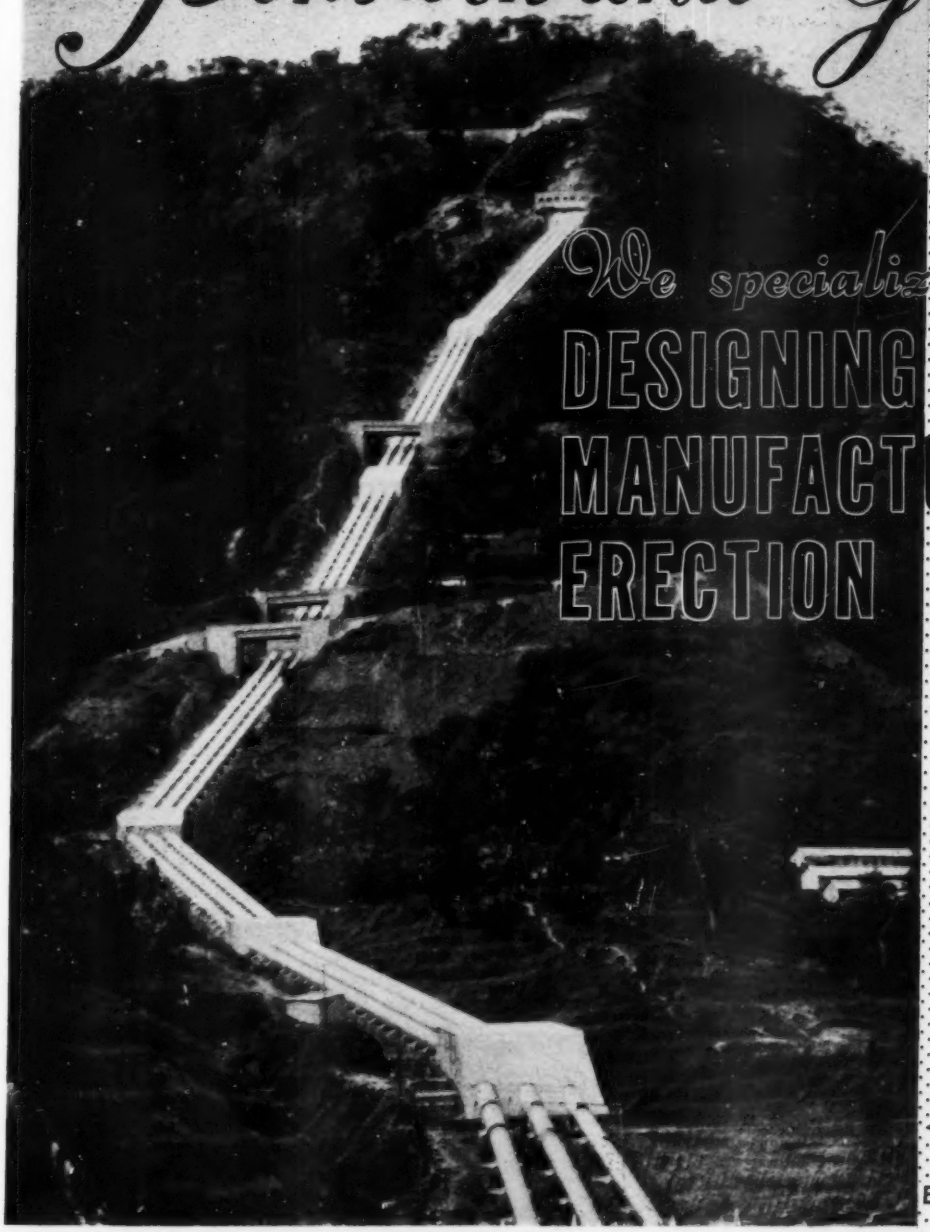

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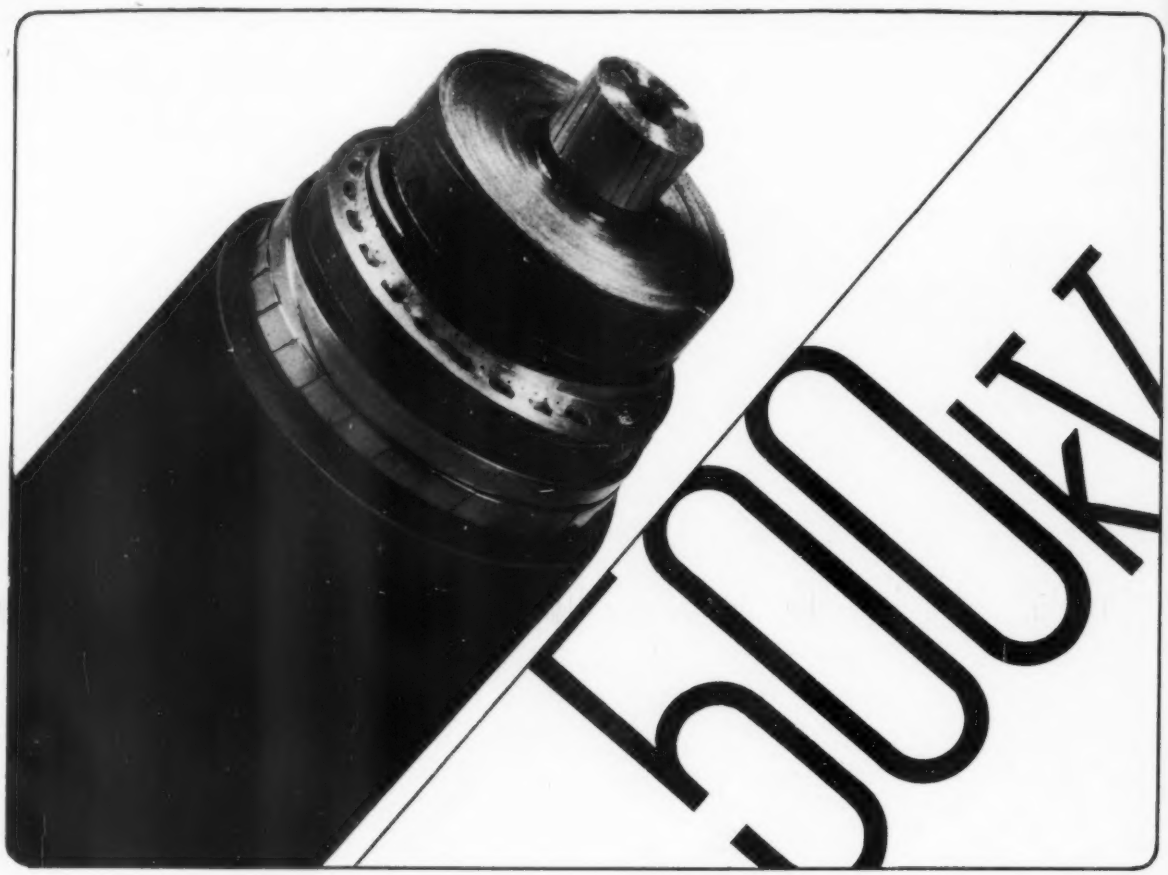
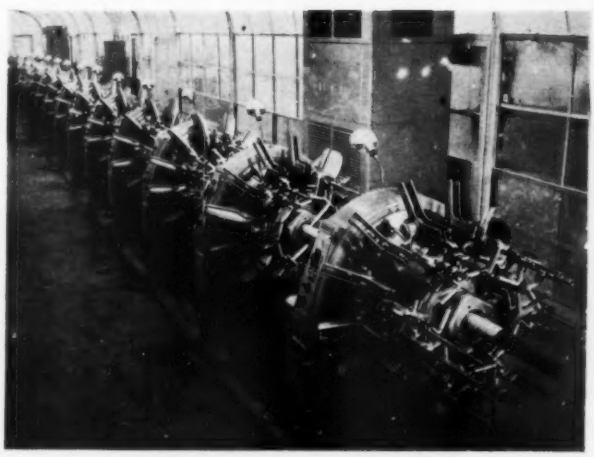


Ready for Tomorrow's Transmission Needs

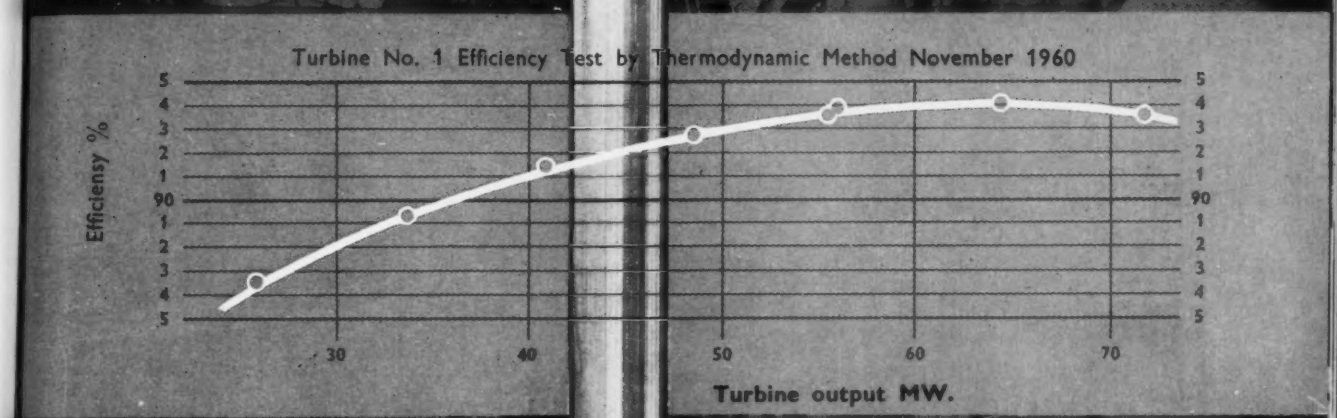
In keeping with the world trend toward a more extensive application of 400kV power transmission, Japan is now adopting the higher rating instead of the conventional 275kV as has been used in the past. This changeover has been reflected in intensified research activities at the ultra-high power transmission testing laboratory incorporated in our new plant at Hitaka. A recent technical tieup with the famous Swedish firm of Liljeholmens was yet another progressive step, and has already resulted in the development and successful testing of a 500kV class $1 \times 540mm^2$ OF cable. Tomorrow's 400kV era will find us ready, as usual, at Hitachi.



▲ *412 Sheets Paper Lapping Machine*

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

KVÆRNER


Turbine No. 1 Efficiency Test by Thermodynamic Method November 1960
Efficiensy %
5 4 3 2 1 90 1 2 3 4 5
30 40 50 60 70
Turbine output MW.

Runner and shaft for Upper Vinstra Power Plant,
rated output 92,000 H.P., 428 rev./min., mean net head 320 metres.
Kvaerner Brug has delivered Francis turbines for
heads up to 543 metres.

A.S. KVÆRNER BRUG
OSLO - NORWAY

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HYDRO-ELECTRIC UNIT

DREES u. CO. GMBH. ABT. 15, WERL GERMANY

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PEN-STOCKS FOR HIGH CAPACITY POWER SCHEMES

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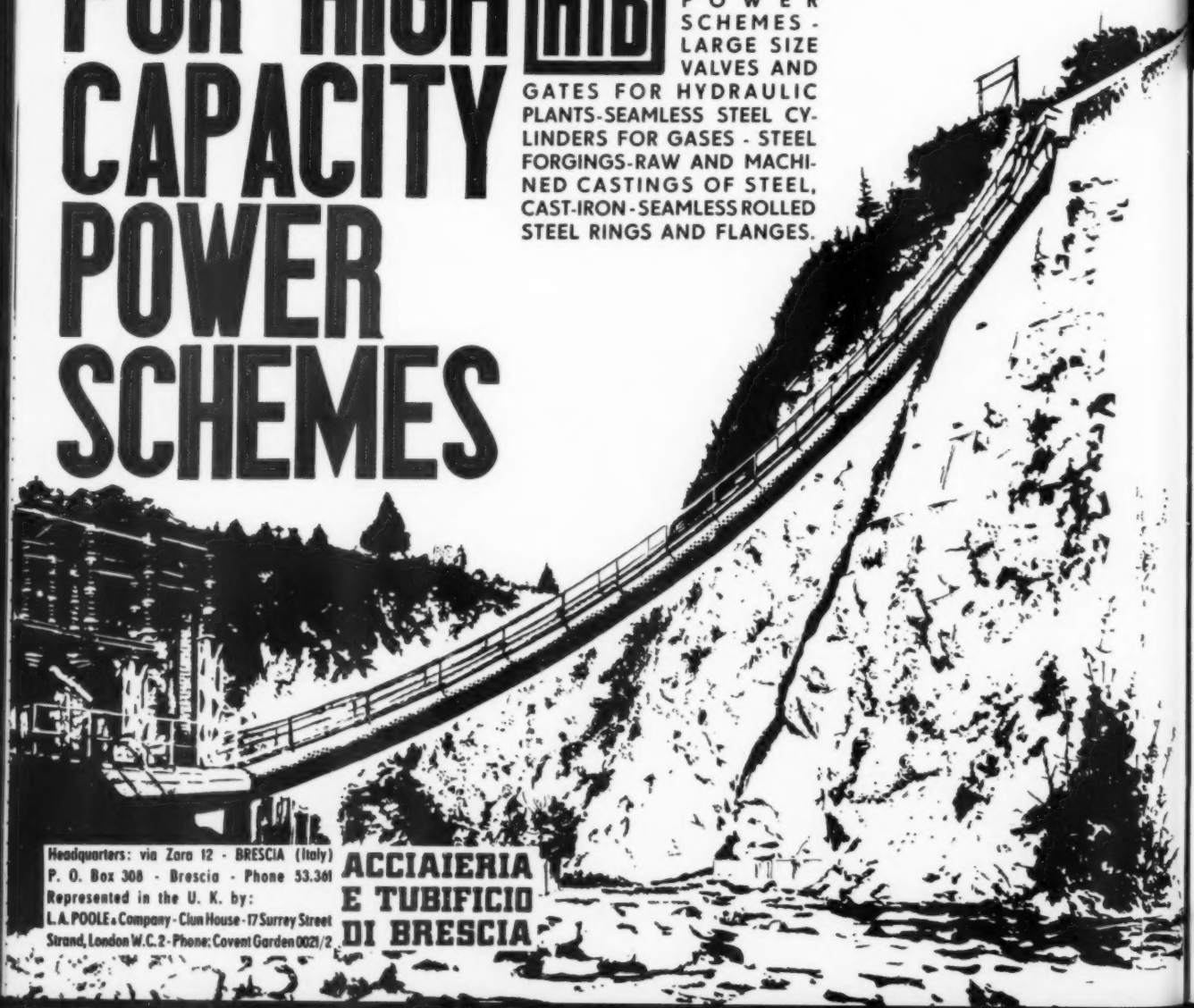
PENSTOCKS FOR HIGH CAPACITY POWER SCHEMES - LARGE SIZE VALVES AND GATES FOR HYDRAULIC PLANTS-SEAMLESS STEEL CYLINDERS FOR GASES - STEEL FORGINGS-RAW AND MACHINED CASTINGS OF STEEL, CAST-IRON - SEAMLESS ROLLED STEEL RINGS AND FLANGES.

Downstream portion of CAFFARO Power Plant (Italy)



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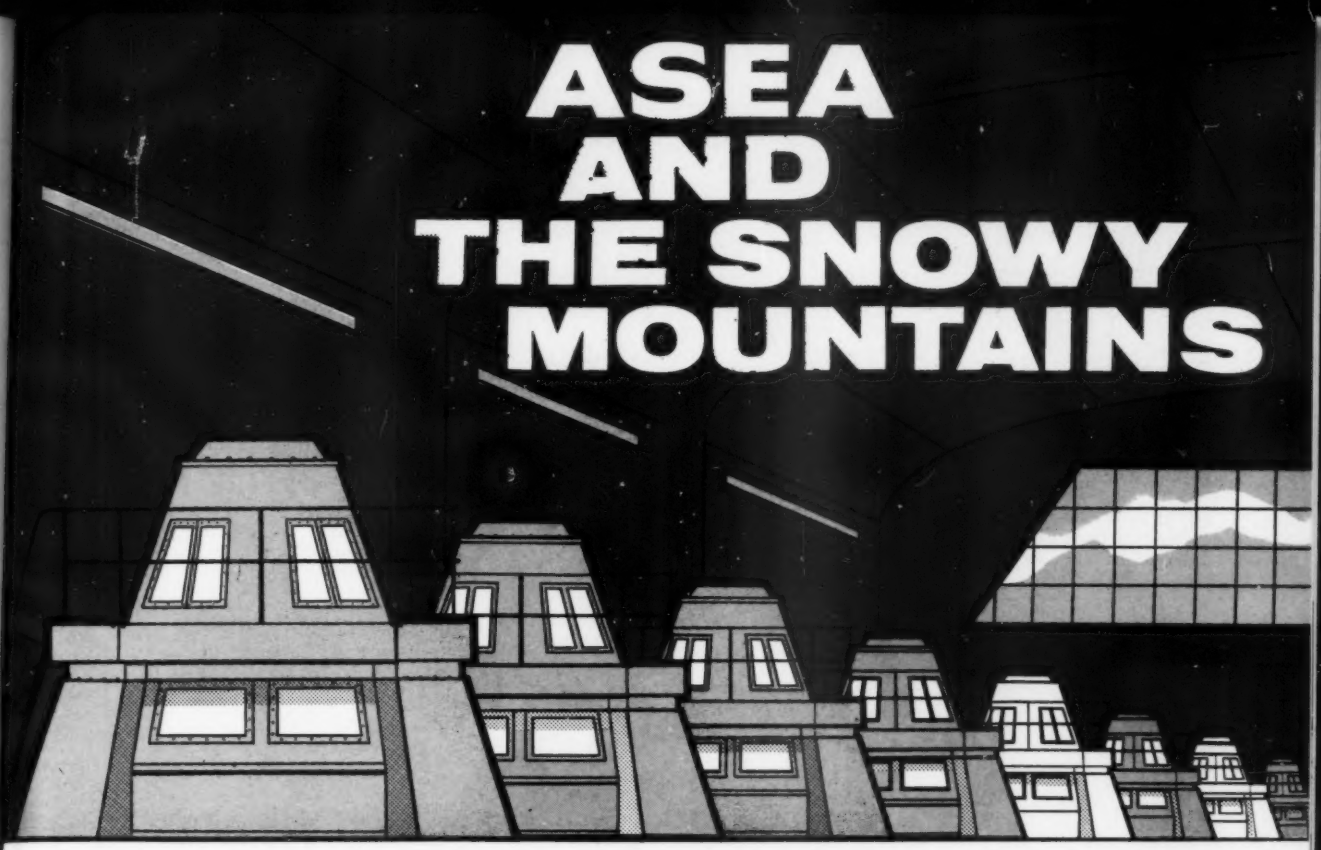
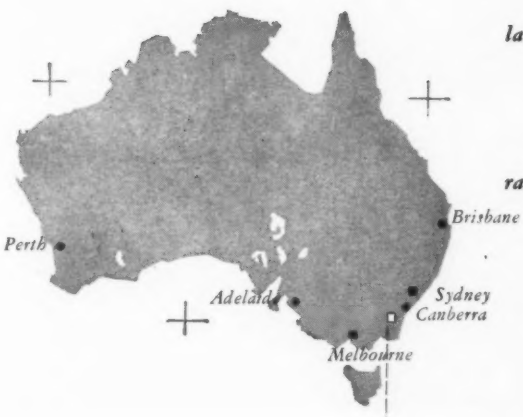
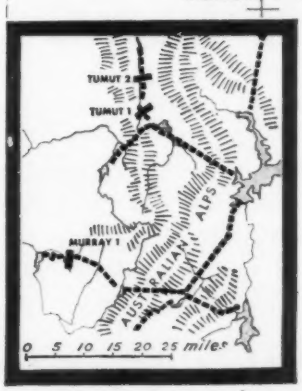
ACCIAIERIA E TUBIFICIO DI BRESCIA

ASEA AND THE SNOWY MOUNTAINS





The map shows the region of the Snowy Mountains in south-east Australia. A vast scheme has been initiated here to provide irrigation for a partly arid area. The broken lines indicate tunnels either completed, under construction or in the planning stage. A number of power-stations have also been constructed. Tumut 1 has already been commissioned, and Tumut 2 will be taken into service later this year. The eight generators, for which ASEA has now received an order, will be incorporated in the Murray 1 Power-station.



For the third time in succession ASEA has received a large order for generators from the same customer — the Snowy Mountains Hydro-Electric Authority, Australia. The latest order comprises eight generators with a total rating of 821,600 kVA. For comparison it may be mentioned that the largest power-station in Sweden, Stornorrfors, has a total rating of 450,000 kVA. Since the first order was received in 1954, ASEA has supplied, or has on order, for the Snowy Mountains 16 generators totalling nearly 1,500,000 kVA.

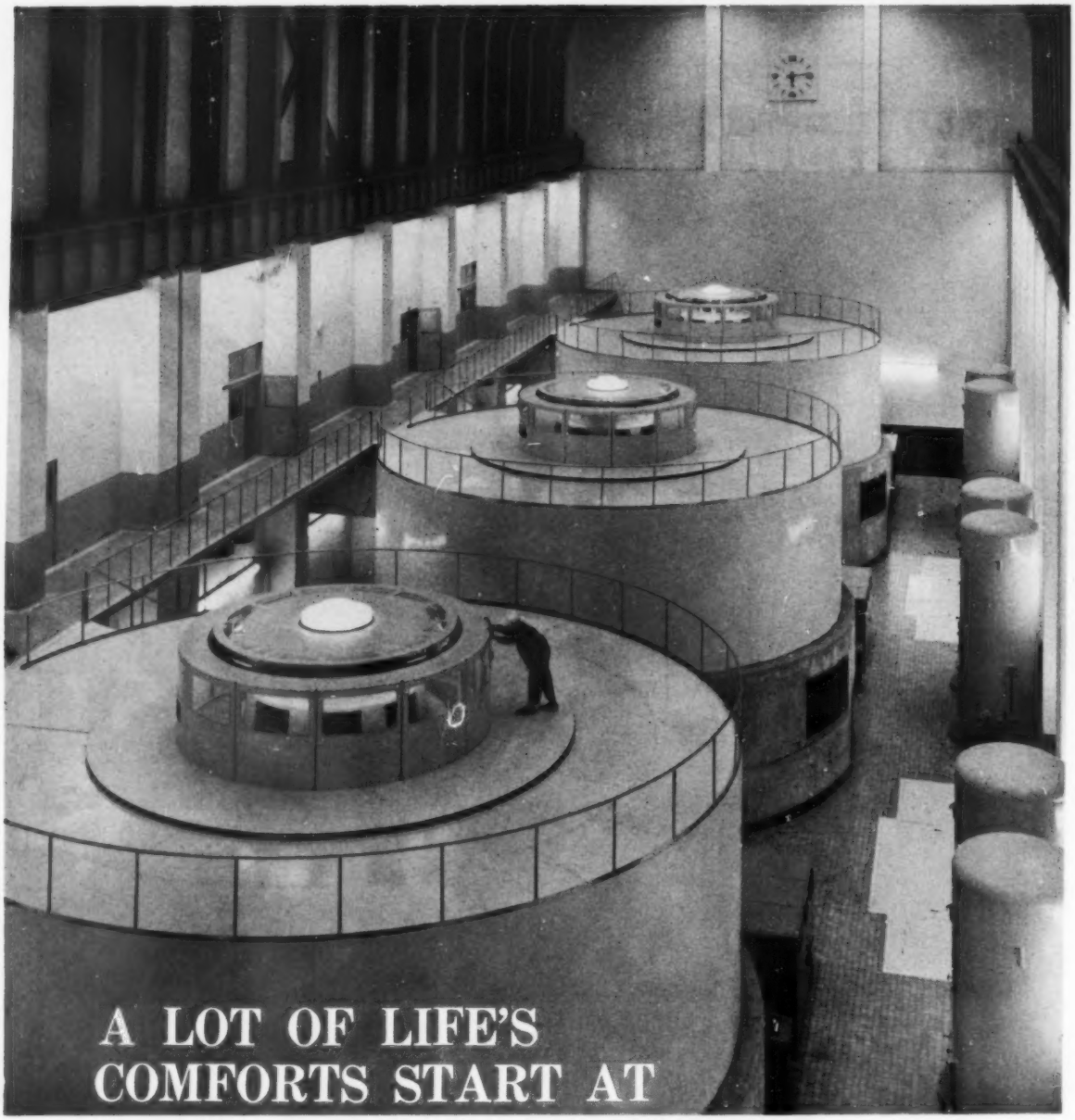
1,500,000 kVA

TUMUT 1	4 generators, each rated at	84,210 kVA, 375 r.p.m.
TUMUT 2	4 generators, each rated at	75,700 kVA, 428 r.p.m.
MURRAY 1	8 generators, each rated at	102,700 kVA, 500 r.p.m.

ASEA

Västerås • Sweden

105,000 kVA Water-Wheel Generators



MITSUBISHI ELECTRIC

When you think of giant generators, you rarely think of their vital part in making this world a more comfortable place to live in. Yet Mitsubishi Electric's great generators and transformers, plus many large and small home appliances all do just that..... every day in countless ways. Backed by a long history of outstanding achievements, distinguished by the famous Mitsubishi Brand. Do think about it the next time you see the THREE DIAMONDS on an electric appliance.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY

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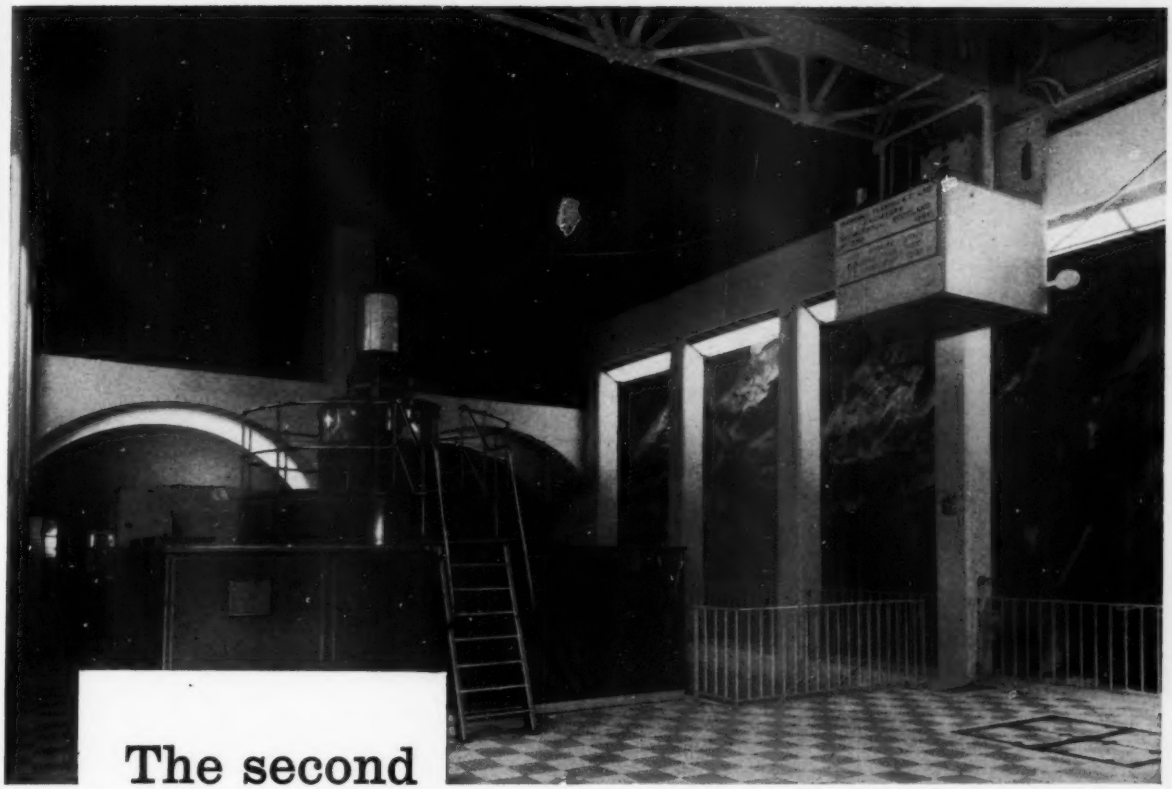

The second underground power station

The St. Fillans Power Station is the second major power station constructed completely underground in the British Isles. Both this and the first major underground station were included in contracts carried out by the Mitchell Construction Co. Ltd.
St. Fillans Power Station forms part of the St. Fillans section of the North of Scotland Hydro-Electric Board's Breadalbane scheme. Mitchell Construction were responsible for the construction on this scheme of two generating stations, 19 miles of tunnelling and numerous intake works and pipe aqueducts.

Consulting Engineers: Sir M. MacDonald & Partners

MITCHELL CONSTRUCTION

Building and Civil Engineering Contractors

THE MITCHELL CONSTRUCTION COMPANY LTD

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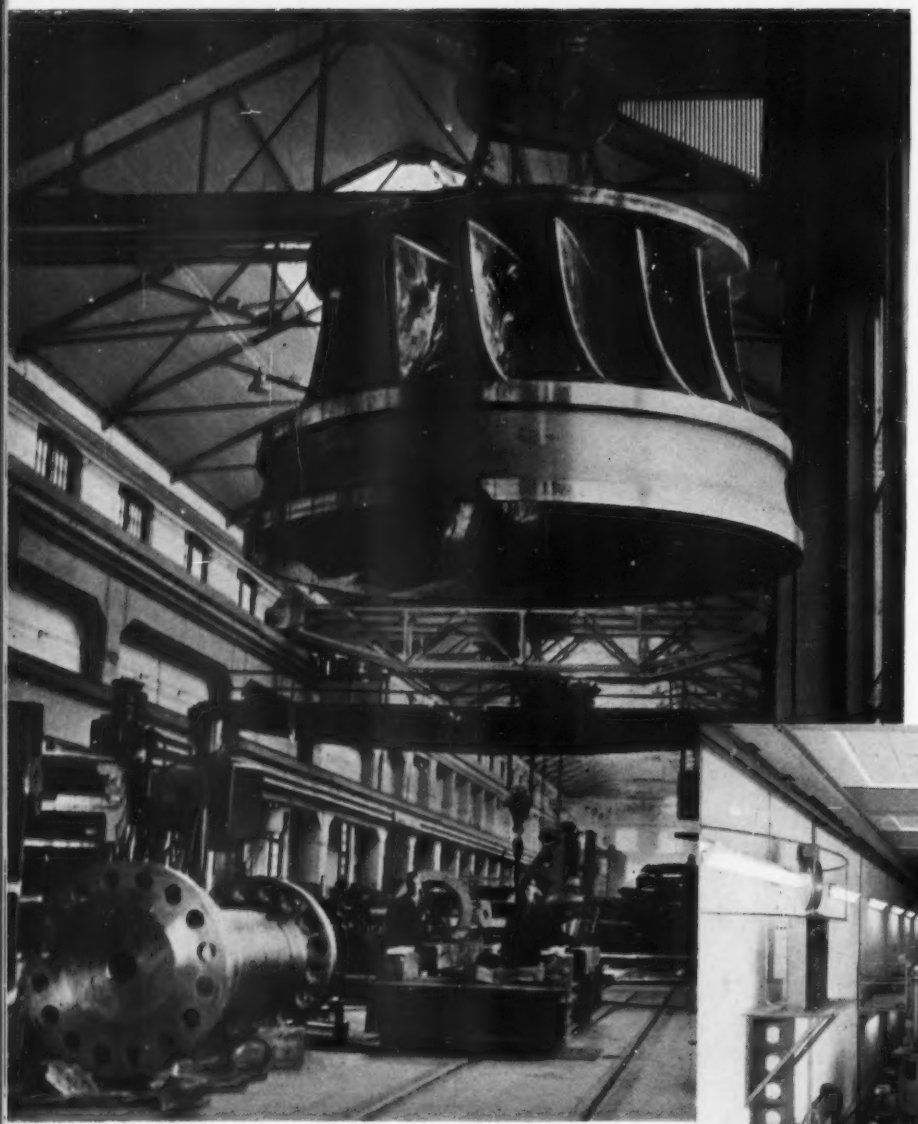
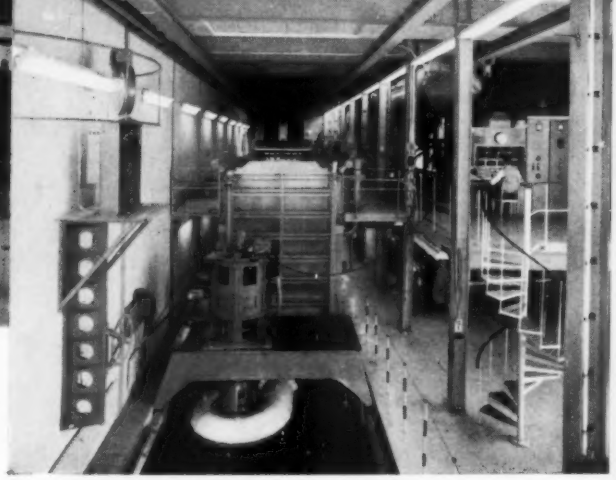
KMW tu



Runner for one of the Harrsele turbines.

The large flume shown below is the dominating feature of the KMW turbine laboratory.



Hydro-electric development on the Ume River in northern Sweden has been the most concentrated in the country. The 350 m (1,150 ft) of head available will be utilised by no fewer than 13 plants. It is estimated that, when fully developed, the river will provide an annual output of 8,100 million kWh. The total sum invested in these plants is expected to amount to about £100 million.

Seven of the 13 stations on the Ume River will have KMW turbines with a total installed rating of roughly 765,000 h.p. The turbines for a further two stations, with a total rating of about 200,000 h.p., are being supplied by a KMW subsidiary company, Finshyttans Bruk.

The first-rate laboratory and workshop facilities at KMW have been decisive factors in the choice of KMW turbines for the stations on the Ume River.

High precision measurements

In the KMW hydraulic laboratory, which is recognised as one of the best equipped in the world, research work is not confined to the conventional types of water turbines, but also embraces bulb units and reversible pump turbines.

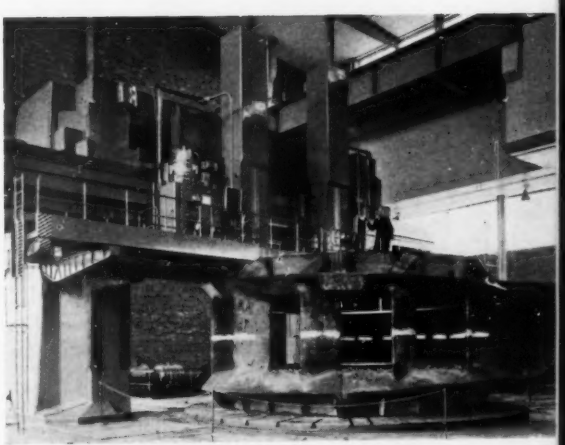
A qualified laboratory staff of technical specialists provide the data required in the various stages of turbine planning, design and manufacture. The equipment they have at their disposal also permits high precision measurements of turbine performance.

Turbines For Power Stations On The Ume River

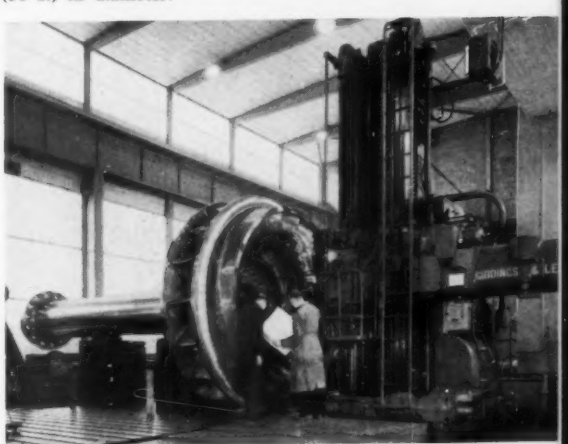
Exceptional production facilities

The workshop equipment at KMW is the most modern available and includes specialised machines for large turbine parts, such as a vertical boring mill which can accommodate a 125-ton workpiece 15 m (50 ft) in diameter, profiling machines and boring machines with 200 mm (7⅞ in) spindle diameter and 11 m (36 ft) longitudinal traverse.

A new modern plate shop and foundry, the largest of their kind in Scandinavia, are also essential parts of the unique production facilities offered by KMW.



Machining a stayring in a vertical boring mill which can accommodate components up to 15 m (50 ft) in diameter.



A Francis runner in one of KMW's large boring machines.

KMW turbines at stations on the Ume River

Station	Type	Total output	Head		Speed
		h.p.	m	ft	r.p.m.
Umluspen ...	2 Kaplan	110,000	30·0	(98)	150
Stensele* ...	1 Kaplan	67,000	18·3	(60)	93·6
Grundfors* ...	2 Kaplan	128,000	34·0	(112)	150
Rusfors	1 Kaplan	55,000	11·7	(38)	71·4
Bålforsen ...	2 Kaplan	110,000	31·0	(102)	150
Bjurfors Övre	3 Kaplan	57,000	11·1	(36)	107
Bjurfors Nedre	3 Kaplan	102,000	19·5	(64)	125
Harrsele ...	3 Francis	264,000	52·6	(173)	125
Pengfors ...	3 Kaplan	66,000	14·7	(48)	125

* Supplied by a KMW subsidiary company, Finshyttans Bruk.

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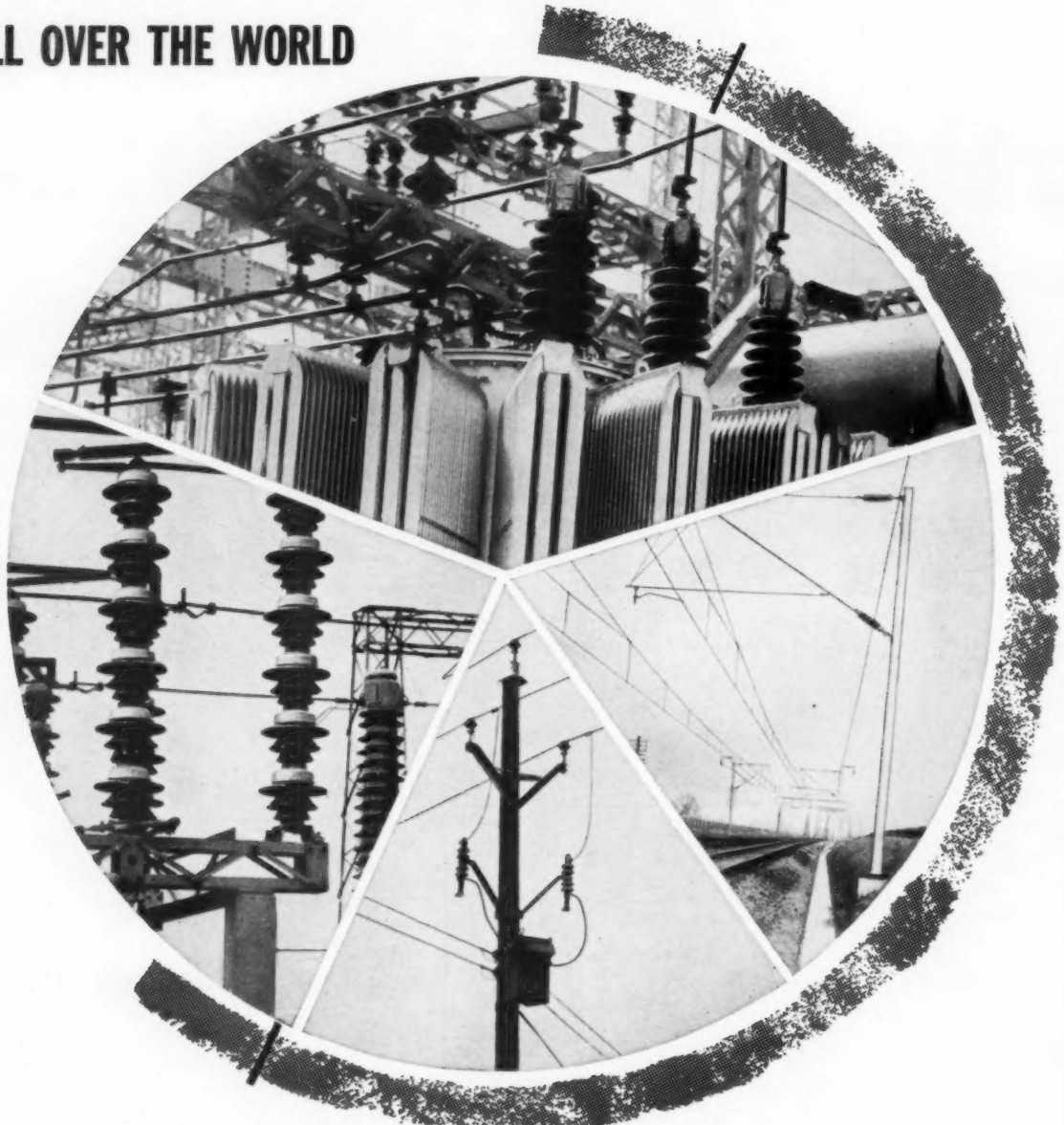
KARLSTAD - SWEDEN

Representatives in Canada: A. Johnson & Co. Ltd., P.O. Box 56, Montreal 16

KMW

ALL OVER THE WORLD



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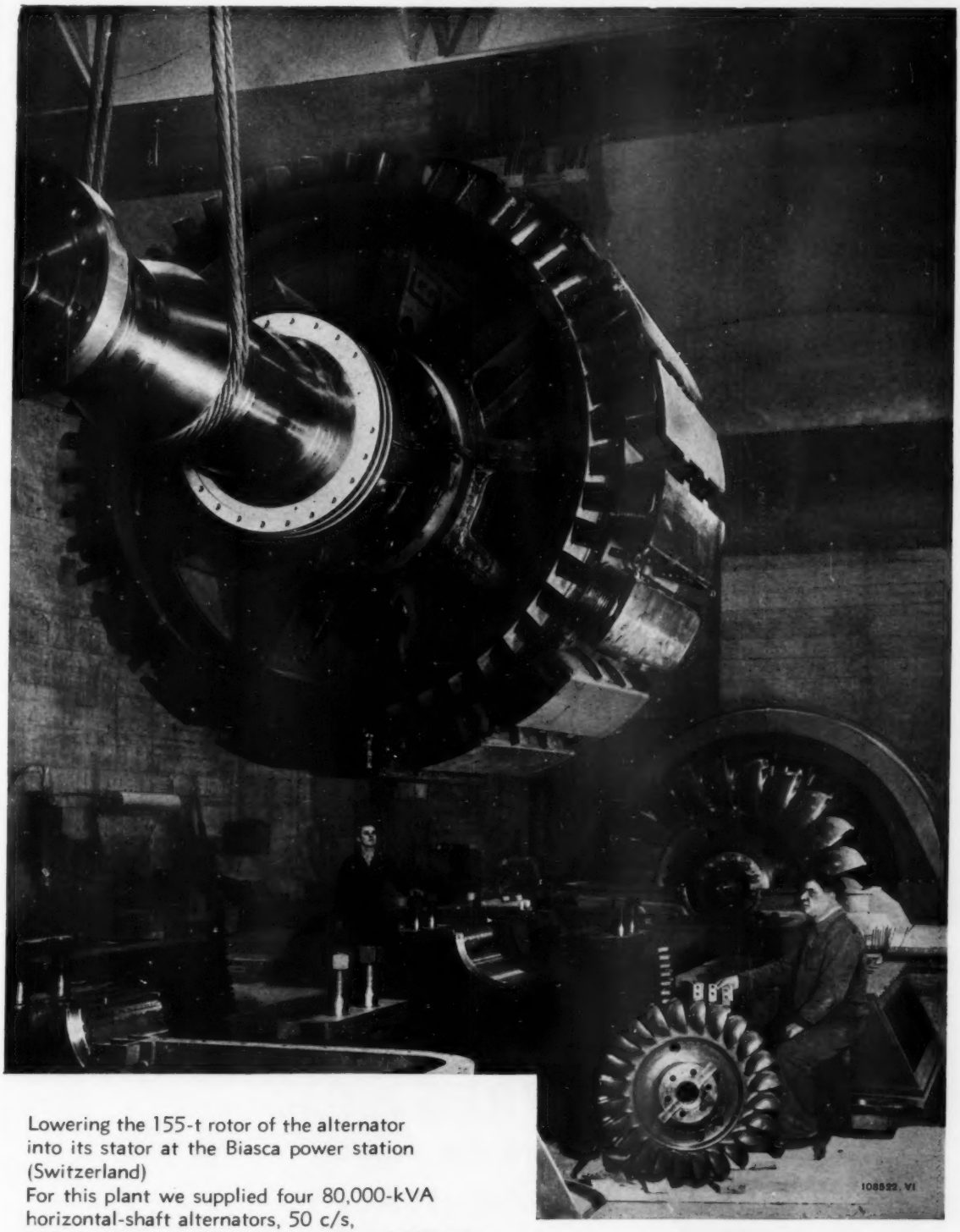
BROWN BOVERI WATERWHEEL GENERATORS



Lowering the 155-t rotor of the alternator into its stator at the Biasca power station (Switzerland)
For this plant we supplied four 80,000-kVA horizontal-shaft alternators, 50 c/s, 333 rev/min, flywheel effect (WD^2) : 1 250tm^2 each coupled to a 100,000 h.p. Pelton turbine

BROWN, BOVERI & CO., LTD., BADEN SWITZERLAND

BROWN BOVERI

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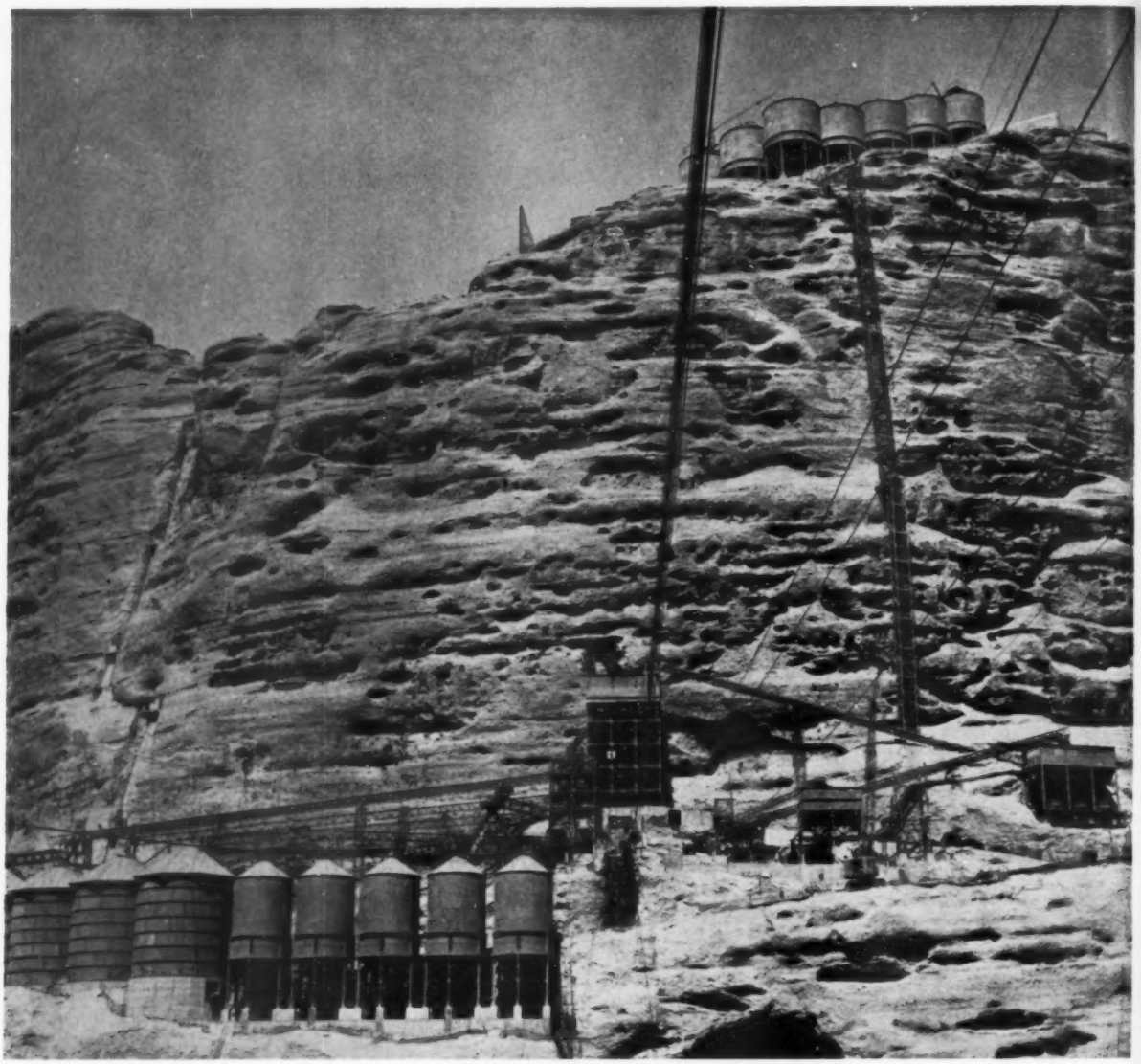
DEVELOPMENT & RESOURCES CORPORATION—NEW YORK

HYDROELECTRIC PROJECT ON THE DEZ RIVER—IRAN

PLAN ORGANIZATION OF IRAN GOVERNMENT



CIVIL WORKS CARRIED OUT BY IMPRESIT-GIROLA-LODIGIANI IN JOINT VENTURE WITH K.G.T.—TEHERAN

IMPRESIT-GIROLA-LODIGIANI

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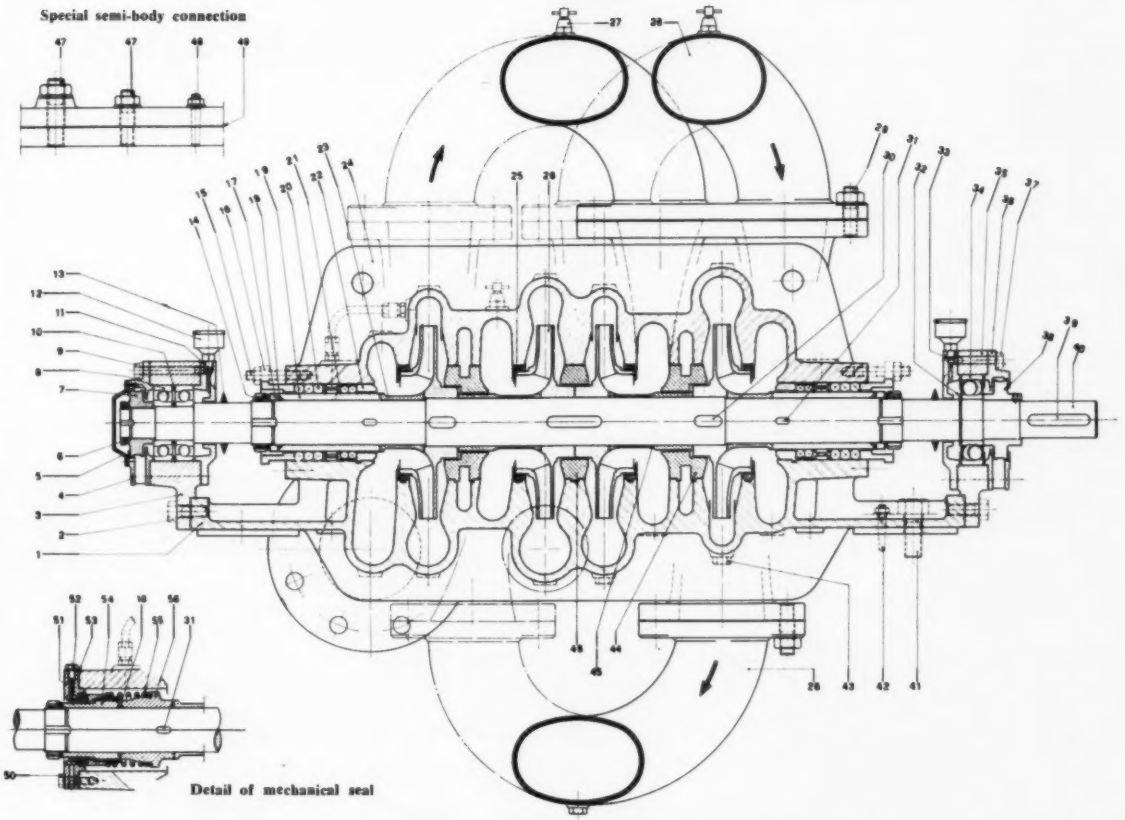
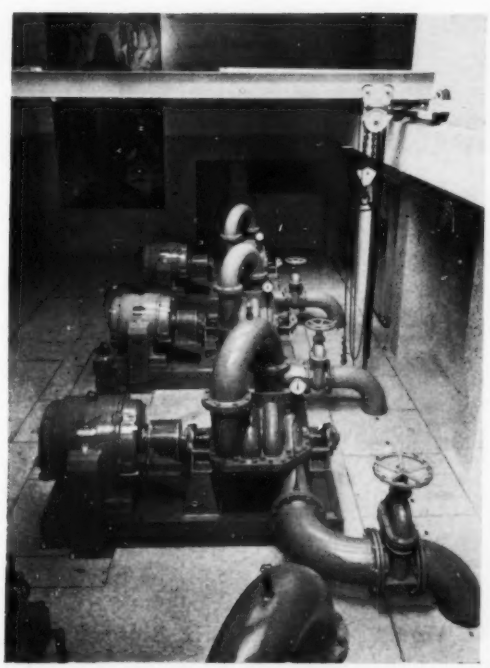
IMPRESA UMBERTO GIROLA

IMPRESA ING. LODIGIANI S.P.A.

PD Pump

For water works, storage plants, industrial works, pumping plants.





PD pumps are of the horizontal shaft, single-suction, multi-stage, centrifugal type. Heavy built, these pumps are highly efficient and have every mechanical feature to assure long trouble-free service.

The body of the pump is split in two halves along the horizontal centerline; therefore, it can be easily inspected and quickly dismantled without removing the pump and disturbing the suction and discharge pipe connections. The impellers are in series and opposed in sets, so as to balance the hydraulic pressures. Axial loads on the bearings are thus eliminated, resulting in a more reliable and trouble-free operation of the pump.

The shaft is of high-strength steel and it is lined with protective sleeves where facing the wearing faces of the stuffing boxes with adjustable stuffing glands. Deep boxes accommodate large packing rings. Suitable connections to the sealing supply line are also provided.

Bearing housings of the outboard type, are provided with grease-lubricated heavy duty ball or roller bearings and thrust bearings, for residual or accidental thrusts.

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A technical journal devoted to the study of all aspects of hydro-electric development

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Volume 13 Number 12

CONTENTS FOR DECEMBER, 1961

Editorial: Adaptation to Change - - - 459

Editorial Notes - - - - - - 460

The Aswan Dam Hydro-Electric Scheme—I - - 463

International River-Basin Development - - - 472

Watershed Resource Value - - - - 474
By Val Gwyther, M.E.I.C., F.ASCE., P.Eng.

The Development of the Ume River—II - - 483

Ninth IAHR Congress—I - - - - 492

Hydraulic Jump in Circular Channels - - - 496
By A. Thiruvengadam

Short Articles: Ice Plant for Bhumiphol Dam—Heavy-Duty Compressor Range—Turbines for Murray I—Adcora Pervon Anticorrosive Coating - - 497

Abstracts from the World Technical Press - - 500

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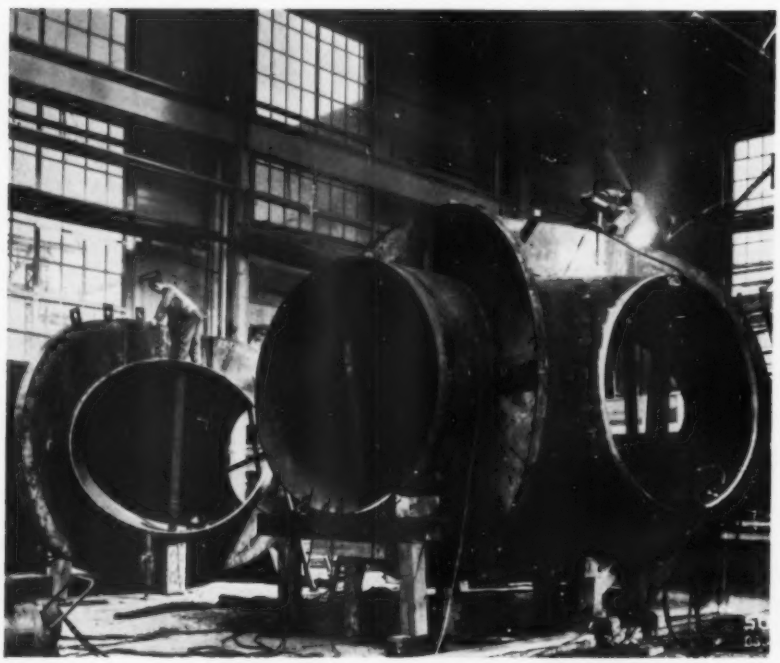
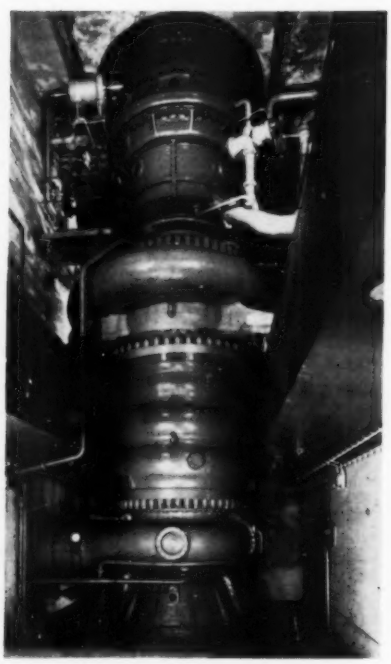


Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Adaptation to Change

IN the field of power technology, as in many others, it is interesting to observe how the pattern of development changes subtly but significantly over the years. Furthermore, as one line of development tends to expend itself another assumes increasing importance. For instance, we venture to think that there has been a connection between the postwar difficulties of the British coal industry and the fact that Great Britain has been a world pioneer in the development of nuclear energy for power production.

Changes of emphasis of this kind are also taking place in hydro-electric practice. In certain countries —for example, Switzerland, Italy and Sweden—the most economical sites have already been built out; although considerable potential remains to be exploited it is relatively more expensive, and in certain cases thermal power is actually becoming competitive. In such countries, too, the full exploitation of the economic water-power potential lies within the foreseeable future, and increasing attention is being paid to the development of conventional thermal and of nuclear power.

But these trends do not imply that hydro-electric engineers will go out of business; the position calls simply for adaptation to change, and this adaptation, in fact, is continuously taking place. In the preceding paragraph the operative word is "economic," and the enormous advances in civil-engineering construction techniques and in high-voltage long-distance transmission have rendered many remote sites economic that could not have been considered even a few years ago.

Again, the approaching saturation of water-power development in some countries is not a world pattern. Even certain European countries are only on the threshold of the development of their water power; the same holds true of many countries throughout the world, and the potentialities of some of the underdeveloped countries are simply enormous. Thus there should be ample scope for the work of the hydro-electric engineer for generations to come.

This adaptation to change is seen nowhere more clearly than in the phenomenal rise of pumped storage. Pumped storage as a principle, of course, is by no means new. A number of pumped-storage plants of small or moderate size have been in existence for many years, notably in Switzerland, where the first plant in the country was installed by Zurich Corporation as long ago as 1883. The building of pumped-storage plants of large capacity, however, is a comparatively recent development. In an article in WATER POWER in 1950 an author stated that "the development of accumulator pumps into the immense units they now assume cannot be regarded as other than striking. Sets have been built with outputs of up to 62,000 h.p. and plants for 73,000 h.p. are in the project stage." The 62,000-h.p. machine was for Provvidenza, and the largest-capacity station mentioned in the article was Schluchsee, which had an aggregate of 98,000 h.p. in four units. Now, at the end of 1961, the following are some of the more notable pumped-storage plants built since 1950 or now under construction: Limburg (125 MW), Sir Adam Beck, Niagara (180 MW), American Niagara (240 MW), Lünersee (225 MW, ultimately 270 MW), Ffestiniog (300 MW), Taum Sauk (350 MW), Cruachan (400 MW), Vianden (400 MW, ultimately 900 MW). Unit sizes have reached the 175-MW machines now on order for Taum Sauk. These capacities are of a totally different order of magnitude from those referred to 11 years ago in our columns—correctly at the time—as "immense units."

This remarkable increase in plant capacity cannot be fully accounted for by a normal trend of development; it reveals that pumped storage is assuming a new significance, and that it will have a vital part to play in the power-supply pattern of the future. Indeed, it is the very trend towards the increased use of thermal power that has brought this about; for one of the most important functions of pumped storage is to conserve off-peak power in thermal systems. Ffestiniog, Cruachan, Lünersee, Taum Sauk and Vianden are large-scale examples of plants de-

signed specifically for this purpose. The overall cost of such a plant has to be balanced against that of an equivalent peak-load thermal station, but the rapid trend towards the installation of large-capacity pumped-storage plants is evidence of their economic justification. As nuclear power comes more and more into use this trend will increase, because the essentially steady-load characteristic of a nuclear power plant will find an ideal partner in pumped storage. Thus we shall find—indeed, we are already finding—pumped-storage plants associated with systems possessing no natural hydro-electric resources. In this connection a development that undoubtedly lies in the very near future is the use of sea water for pumped storage.

Pure hydro-electric systems, however, will also benefit increasingly from pumped storage, because it can be used to save run-of-river power that would otherwise be wasted or to store up the spring snowmelt for use during the following winter.

Another remarkable advance in this field has been in the development of the pump-turbine. When the Hiwassee 60-MW reversible machine was installed in 1956 it was acclaimed—we believe correctly—as the largest machine of its kind in the world, but the reversible machines for Taum Sauk will be rated at 175 MW. There has also been a great change in the heads for which pump-turbines have been designed. The Hiwassee machine operates against a head of 172 ft; at Taum Sauk the head will be 800 ft, the new Deriaz machine for Provvidenza is designed for a head of 850 ft, and the Cruachan pump-turbines will operate under a head of 1,100 ft—believed to be the highest head for which such machines have yet been designed. The technical problems in the design of a reversible machine are pretty formidable—they were admirably set out by H. Headland in his nominated lecture to the Institution of Mechanical Engineers* a year ago—but, as is evident from the progress made in the past five years, immense strides are being made.

At the other end of the head scale the past decade has seen the development of the two-directional tubular-type pump-turbine which has made the Rance tidal scheme a feasible proposition. This may well prove to be epoch making.

In these and in many other ways engineers in the hydro-electric field are displaying an adaptability in the face of changing conditions that augurs well for the future. We look forward with confidence, and with no little curiosity, to contemplating the picture that will be presented in 1972.

Nuclear Power in the Philippines

THE International Atomic Agency, Vienna, has published a report entitled "Prospects of Nuclear Power in the Philippines," forming No. 3 of the Agency's Technical Reports Series. The report includes an objective survey of the various power resources of the Philippines, and has much of interest to say as to the place of water power in relation to the overall pattern of demand in Luzon. The hydro potential on the island is roughly estimated at 2,000 MW, but the main difficulty in making such an assessment is lack of information because for most rivers reliable flow records have not been kept for a sufficient length of time. A second consideration is that Luzon is in the monsoon region and storage facilities are limited, so that annual plant factors average only about 50%. Tables are given showing the major hydro-electric plants in existence and planned in Luzon, and there is a map showing hydro-electric developments throughout the Philippines. It is urged that full use be made of the economic hydro-electric capacity and that a sustained programme of river gauging be instituted. Water power, however, will not be sufficient to meet future demands on the Luzon Grid, and other sources of power, both conventional and nuclear, must also come into the picture. Cost comparisons indicate that a nuclear power station consisting of two 100-MW units installed in the Manila area in 1967–68 may be competitive over its lifetime with an oil-fired station of the same size, but this should be confirmed by a careful evaluation of international tenders for both types of plant.

* Summarised in the Leader of our February 1961 issue.

IAHR Japan Meeting

THE Japanese local committee of the International Association for Hydraulic Research is organising a Symposium on Cavitation and Hydraulic Machinery to be held in Sendai and Tokyo from September 3–8, 1962. The section on cavitation will cover the mechanism of cavitation inception, experimental techniques, scale effect, profile performance, and erosion; hydraulic machinery will include water turbines, pumps, pump-turbines, fluid couplings, ship propellers, and general machinery, and the papers under this heading will be related as far as possible to cavitation. Enquiries about this conference should be addressed to Prof. F. Numachi, Chairman, Local Organising Committee, IAHR Symposium on Cavitation and Hydraulic Machinery, Institute of High Speed Mechanics, Tohoku University, Sendai, Japan.

Bulb Turbines for Loch Awe

THE North of Scotland Hydro-Electric Board have recently placed a contract with the Armfield Hydraulic Engineering Co. Ltd. for the supply and erection of two bulb-type water turbo-generators for the Awe dam in Argyllshire. These two units will be the first true bulb-type machines installed in the United Kingdom. The dam, which is situated near the outlet of Loch Awe, will serve to divert the flow of water into a new tunnel being provided to supply the hydro-electric plant at Inverawe power station near the outlet of the River Awe. Loch Awe will also constitute the lower reservoir of the new Cruachan pumped-storage scheme. The units supplied for the Awe dam will each be designed to develop 695 h.p. at a net head of 22·5 ft. The Armfield Hydraulic Engineering Co. Ltd., who act as main contractors, are supplying bulb turbines manufactured by Ets. Neyrpic, Grenoble, driving induction generators made by Alsthom of Belfort. Commissioning of the bulb units will take place in early August, 1962. The work on the dam is already well advanced and the turbine embedded parts are scheduled for site erection by May, 1962.

The Armfield Hydraulic Engineering Co. Ltd. has also been awarded the contract for the turbine inlet gates and outlet gates. The inlet gates are of the stop-log type, whereas the outlet gates are hydraulically operated, gravity-closing, fixed-roller gates, which are used to bring the turbine to rest. The electrical and

mechanical engineering consultants for the Cruachan and Inverawe sections of the Awe scheme are Merz & McLellan, and the civil consultants are James Williamson & Partners.

Snowy-Murray Civil-Engineering Contracts

THE Snowy Mountains Hydro-Electric Authority has placed three contracts totalling £A20,887,000 (£16,709,600) for work on the first major stage of the Snowy-Murray development. Tenders were received from eleven large contracting organisations, including Australian and British concerns, but the contracts have been awarded to an American joint venture comprising Utah Construction and Engineering Proprietary Limited, Brown and Root, and Sudamericana Limited. The three contracts cover the construction of the 15-mile Snowy-Eucumbene tunnel, the Island Bend dam, and the Snowy section of the Snowy-Geehi tunnel. Further tenders are shortly to be called for work on the Snowy-Murray scheme, as Murray 1 station, together with its associated dams and tunnels, must be completed by 1966 to meet the anticipated electrical demand.

Water-Resource Investigation in Ethiopia

IN accordance with a contract signed by SOGREAH (Société Grenobloise d'Études et d'Applications Hydrauliques) with the Food and Agriculture Organisation of the United Nations, a general study has been undertaken of the basin of the Awash in Ethiopia. In this investigation, which will occupy three years, information will be collected on the river régime and on the agricultural possibilities of the valleys and lowland plains, and then a scheme will be elaborated for the optimum utilisation of the waters and of the terrain, with particular reference to water regulation, hydro-electric development, and the use of irrigation to bring new territory under cultivation. The preliminary survey will cover 500,000 hectarea. The Ethiopian Government is participating in these investigations.

Aschach Lock in Service

ÖSTERREICHISCHE DONAUKRAFTWERKE AG announce that the south chamber of the twin locks associated with Aschach power station was opened to regular service on October 16, 1961. Similar in pattern and size to those of other Danube installations at Kachlet, Jochenstein and Ybbs-Persenbeug, these locks can accommodate in each chamber, in addition to the tug, a train of four 1,200-ton barges coupled in pairs. Owing, however, to the higher head of water in the Aschach lock chambers (16·0 m as against 10·5 m at Ybbs-Persenbeug) and the substanially greater volume of lockage water (90,000 to 120,000 m^3 as against 60,000 to 90,000 m^3), the designers had to solve the difficult problem of keeping strictly to the fifteen-minute filling and emptying time operating at Ybbs, while avoiding any surge in the head and tail bays which might endanger navigation, and at the same time ensuring a uniform and smooth raising or lowering of the boats in the lock chamber. The solution adopted after extensive model tests simply consists in drawing the lockage water direct from, and releasing it direct into, the main river stream, and not from or into the bays. This was achieved by building into the floor of each chamber two culverts connecting at either end with the main river stream by means of conduits provided in the north wall of the lock; in addition, the roofs of these culverts, which lie flush with the floor of the chamber, are fitted at regular intervals with 5-cm slots, and there is a system of intercommunication between the two culverts, so that filling and emptying occurs uniformly throughout their whole length.

Turbines for Markham Ferry

THE Grand River Dam Authority of Oklahoma, U.S.A., has awarded the English Electric Corporation of New York a contract worth some 2½ million dollars (£900,000) for the design, manufacture and delivery of four 35,000 h.p. 90 r.p.m. Kaplan water turbines with a runner diameter of 220 in for a new dam and power station on the Grand River at Markham Ferry, Oklahoma. The turbines will be manufactured by John Inglis Co. Ltd., of Toronto, an associate of the English Electric Co. Ltd. The design work will be done by the Company's Hydro-Electric Division at Netherton and the model testing and development will be carried out in their hydraulic laboratories at Rugby. The consulting engineers for the project are W. R. Holway & Associates, of Tulsa, Oklahoma, who have also been responsible for the construction of an earlier dam at Pensacola on the Grand River.

Markham Ferry will be a gravity and rockfill dam, providing a mean head of 55 ft. As well as affording a measure of flood control, the new power station will supply the State of Oklahoma with an additional 100 MW of plant capacity. It is planned to have the dam completed and the power house in operation by May, 1964.

Miboro Dam Inaugurated

MIBORO DAM, on the Sho River, Japan, was officially inaugurated on October 24. It is the largest rockfill dam in Japan and one of the largest in the world, and was built by Hazami-Gumi K.K., who commenced operations in 1957 and completed the dam in November 1960. Rockfill was placed at an average rate of 22,000 m^3 per day. The Miboro development, which was briefly described by Prof. Kito in our October issue, has a capacity of 225 MW and cost Y40,000 million (approximately £40 million).

Swiss Progress in 1960-61

THE Annual Report of the Swiss consulting engineers Motor-Columbus SA, Baden, gives an interesting picture of the electricity-supply position in Switzerland during the year ended October 30, 1961. Consumption during the twelvemonth was 17,703 GWh excluding power used for electric boilers and for pumped storage, an increase of 7·9% on the previous year. Thanks to favourable hydrological conditions, generation during the winter half-year of 1960-61 was 10,037 GWh, and during the summer half-year 11,388 GWh—increases of 35% and 16·5% respectively. Storage reservoirs, which were filled to 96% of their capacity, represented a reserve of 4,080 GWh as against 3,750 GWh a year previously. The increase in hydro-electric production resulted in an export of 864 GWh as against an import of 959

GWh in the preceding twelvemonth. Hydro-electric power, however, represented only 20·5% of the country's gross energy requirements, taking heating and motor transport into account. This percentage has remained fairly steady for some years and is expected to continue to do so. Nevertheless, as the most economical water-power sites have now been developed, the economics of proposed new schemes have to be weighed with care, as some of them are hardly more economical than thermal power.

Turning to schemes in which Motor-Columbus have been retained, excellent progress is reported on the Hinterrhein scheme. Sils power station is now in full commission, the Valle-di-Lei/Ferrera stage is approaching completion, and the Sufers-Bärenburg stage is progressing rapidly. Lona power station, belonging to Gougra SA, has been placed in operation, and work on the three stations of Blenio SA is proceeding to schedule. The firm has collaborated in the designs for the S-chanf-Pradella and the Livigno/Ova-Spin stations of Engadine SA, and preliminary studies of the Franco-Swiss Emosson development have been pursued on an international level. Design work has also been commenced on the Flumenthal station for Aar & Tessin SA and on Giumaglio station for Società Elettrica Sopracenerina. Important work has been done on high-voltage transmission lines, and work in other countries has included the Huinco station of Lima Light & Power Company and the Gaver-Rimal station of Società elettrica ed elettrochimica del Caffaro of Milan.

British Turbines to be Manufactured in India

GILBERT GILKES & GORDON LIMITED, Kendal, England, have concluded a technical aid agreement with Jyoti Limited, pump and water-turbine manufacturers, Baroda, India, whereby Jyoti Limited will receive technical assistance in the manufacture of water turbines, governors, etc., to certain of Gilkes designs. Jyoti Limited manufacture a range of standard adjustable-blade propeller and small Francis and cross-flow turbines which have primarily been designed as standard units for use on canal falls and for village lighting in the more mountainous parts of India. Gilkes designs will be used more particularly for larger units and for higher-head installations where Turgo impulse and Pelton wheels will be required. Jyoti Limited will also act as distributors for Gilkes turbines that cannot economically be manufactured in India.

Progress of Benmore Scheme

ACCORDING to Mr. J. W. Ridley, project engineer in charge of hydro-electric works in the Waitaki valley, the Benmore hydro-electric project is more than one-third complete. The earth dam is more than one-third complete, three-quarters of the spillway block has been completed, the intake for the penstocks is about half completed, and the excavations for the power house have been made and concreting begun. A large switching station near the power house at Benmore will transmit power at 500 kV direct current to Haywards by the Cook Strait cable. The capacity of the link will be 600 MW.

Development of the whole of the upper Waitaki basin is also under consideration. Specific designs are being prepared for Aviemore, drilling and prospecting are being undertaken for the earth dam and the concrete, and the site is being opened up for construction to begin next year. There is a scheme for taking a canal from Tekapo to Pukaki for power stations at Maryburn and Pukaki. The project at Maryburn would provide 60 MW and at Pukaki 130 MW. A large power station at the head of the projected Benmore lake at the Ohau bridge would have a capacity of 500 MW.

World Bank Development Service

THE World Bank has established a new Development Advisory Service designed to provide a corps of expert talent available to furnish economic and financial advice to the governments of the less-developed member countries of the Bank, particularly in connection with the preparation and execution of development programmes. The establishment of the new service, and related organisational changes, are part of a general policy of enlarging the Bank's technical assistance and training activities.

Northern Canada Power Commission

IN the Annual Report of the Northern Canada Power Commission for the year ended March 31, 1961, the main item of hydro-electric interest is the account of the Snare Falls plant, which was placed in service in December 1960. This plant, which consists of a 7,000-kVA vertical Kaplan unit, is situated about 10 miles downstream from the Snare Rapids station and is remote controlled therefrom. An earth dam, 450 ft long by 75 ft high, impounds a storage of 1,500 acre ft and creates an effective head of 63 ft. A power canal, 400 ft long by 30 ft wide, leads from the reservoir to a spillway structure and to the intake for a 17-ft penstock tunnel, 95 ft long and with a 14-ft steel liner, supplying an indoor-type power station.

The report also records that preliminary studies were undertaken at Glacier National Park to determine whether a hydro or a diesel plant would be the more economical scheme for future power development.

Contract for Tanganyika Station

AN order for two 10·5-MW vertical Francis generating sets for the Hale scheme on the Pangani River, Tanganyika, has been placed with The English Electric Co. Ltd. These sets are to be installed in an underground station about 40 miles upstream from the port of Tanga, and are scheduled to go into operation early in 1964. The value of the contract is some £300,000, and the company has also been awarded a £30,000 contract for 33-kV substation switchgear.

The design and construction of the civil works and of the transmission line have been entrusted to Balfour, Beatty & Co. Ltd. The total cost of the scheme will be about £5 million.

Water-Weed Control. Borax Consolidated Limited, of Borax House, Carlisle Place, London, S.W.1, have sent us an informative leaflet describing their product Dalacide, which is a chemical for use in the control of water weeds in channels. A variety of reeds, rushes and sedges are said to be effectively controlled by this material when used in a fine spray.

Fig. 1. Diorama of the Aswan hydro-electric scheme (Hunting Aerosurveys Limited)

The Aswan Dam Hydro-Electric Scheme

This is the first of three articles describing the 350-MW installation at the Aswan dam on the River Nile. The project is of particular interest in that the plant is subjected to a wide range of heads owing to the paramount irrigation requirements. This article outlines the development of the scheme, and describes the excavation works and the intake dam

PART ONE

THE development of the Nile Valley to serve the needs of its ever-increasing population has a long and fascinating history, and no single project on the Nile has commanded so much interest as the Aswan dam, which is some 600 miles south of Cairo and situated at the head of the series of rapids known as the First Cataract.

Due to the seasonal nature of the rains that supply the bulk of the flow in Egypt's Nile, the discharge varies considerably over the year, and for many thousands of years single crops were grown following the recession of the annual flood. In the 19th century this method of basin irrigation became increasingly inadequate and a perennial irrigation system gradually superseded it. By the end of the century the whole of the Nile flow during the low-flow period was being utilised and it became imperative to augment this supply by storing some of the flood discharge. Considerable thought was given to the means by which this storage could be effected, and eventually the original Aswan dam was constructed between 1898 and 1902. This structure, which was designed by Sir Benjamin Baker, stored 980 million m^3 of water at an elevation of 106·00 m.* One of the most outstanding features of this dam was the provision of 180 low-level sluices. The large area of waterway resulting was essential to the free passage of silt, which is considered a vital addition to the irrigated soils.

The immediate success of the Aswan dam soon resulted in demands for greater quantities of stored water, and the structure was heightened in 1912 by 5 m to an elevation of 114·00 m and the top water level raised to 113·00 m, thereby increasing the storage capacity to 2,400 million m^3. By 1927 the population of Egypt had more than doubled in less than 50 years and an even greater capacity was now required. The dam was therefore raised again, this time to a road level of 123·00 m, with a maximum reservoir level of 121·00 m and a storage capacity of some 5,000 million m^3. The work was completed in 1933. The design of the first heightening was entrusted to Sir Benjamin Baker and the second to Sir Murdoch MacDonald, and the not inconsiderable problems were overcome with a high degree of ingenuity.

The existing Aswan dam is a masonry structure 2,129 m long and 35·50 m in maximum height above river-bed level. The original dam was essentially of the gravity type, but the second heightening involved the construction of buttresses between the sluices, which are spaced 7 m apart, and are in groups of ten. These sluices are 2 m wide and are controlled by roller gates operated from the dam

* The reservoir levels are referred to an arbitrary datum, which is 82 cm below mean sea level at Alexandria, and 1·80 m below the Egyptian Survey datum.

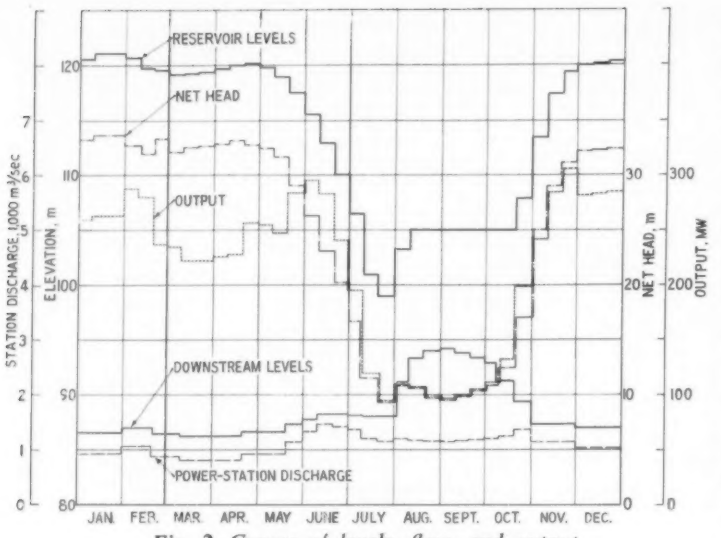


Fig. 2. Curves of levels, flow, and output

crest. The dam is bypassed at the western end by five navigation locks in series.

Power Development

Almost from the time of the completion of the original dam, schemes for the generation of electricity at Aswan were propounded, and by the time the second heightening was assured the possibility of a hydro-electric installation was being given serious attention. The higher reservoir level meant that a considerable output could be achieved, and the increasing use of Kaplan turbines for low-head developments and of high voltages for long-distance transmission made the scheme appear more attractive. Furthermore, the demand for electrical energy in Egypt was steadily rising, and the possibility of producing fertiliser, of which large quantities were then imported, was being considered. In 1932 several well-known Egyptian engineers of the Electrical and Mechanical Department of the Ministry of Public Works prepared comprehensive proposals for a power scheme but these were not acted upon.

In June 1945, the Egyptian Council of Ministers established a Hydro-Electric Power Commission under the chairmanship of Dr. Abdel Aziz Ahmed. The original members of the commission were Mustafa Fathy, Ahmed Khairy, Dr. Hassan Zaky, Sayed Abdel Gawad, the late S. B. Donkin and Geoffrey Kennedy. The membership was later enlarged to include the late Dr. H. E. Gruner and Valter Furuskog. The commission was entrusted with the design and execution of a hydro-electric development at Aswan.

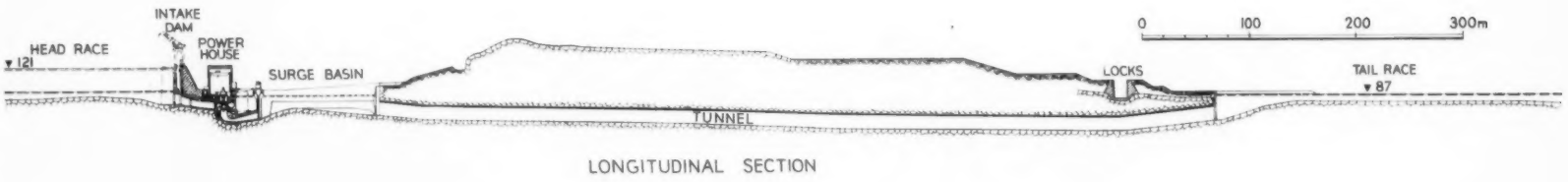
At all stages in the evolution of the concept of a power installation, it was repeatedly emphasised that any such scheme must be completely subordinate to the irrigation needs of the country, i.e., the scheme was required not to interfere with the normal storage regulation procedure. Since the regulation resulted in a variation of net head of from about 7 m to more than 33 m, some ingenuity was called for. It was agreed with the Irrigation Department that, during periods of high reservoir level, the whole of the flow that would normally be released for irrigation purposes downstream could be utilised for power purposes. It was also decided that the installed capacity should be sufficient to develop full power from the available water in the high-head season plus enough spare plant to allow all maintenance work to be carried out at the same time. During the low-head season it was planned to operate all the plant but at reduced output.

The commission authorised the project and decided to proceed with what has been termed the "penstock scheme." It had been calculated that the flow from four sluices in the existing dam could produce 65,000 h.p. and that the length of 28 m occupied by these sluices could conveniently accommodate a spiral casing of the necessary size. It was therefore decided to utilise 30 sluices to supply seven 65,000 h.p. Kaplan turbines and two 16,000 h.p. machines. These turbines were to be coupled to 49·5-MVA and 13·5-MVA alternators respectively, and thus the total rated capacity would be 373·5 MVA.

The 30 sluices that it was proposed to utilise are at the western end of the Aswan dam, between the west bank of the Nile and the Island of Habs (see Fig. 3). This part of the river, known as the Western Channel, is the deepest section and the sluice sills are at a level of 87·65 m. It was proposed to install in each sluice three 1·8-m diameter steel pipes in vertical formation. These were to be enlarged to 2·25 m diameter downstream of the sluice, and to be connected to sets of pipes from adjacent sluices, in groups of four for the main turbines, by means of manifolds. In this way the discharge from four sluices was to be directed to each turbine. The turbines were to be located some 120 m downstream of the upstream face of the dam, and to be separated from the manifolds by surge tanks. The power station was to have been founded on the rock underlying the river bed, and the switching station sited on the Island of Habs.

In late 1947 contracts were placed for the main items of plant for the penstock scheme, and in October of that year a contract was placed with the Société de Construction des Batignolles for the excavation for the foundations and draft tubes, the construction of a permanent masonry wall connecting the dam to the Island of Habs, and the construction of a cofferdam connecting the island to the west bank of the river. This work was completed in 1950.

A body of informed opinion in Egypt had for some time opposed the idea of interfering in any way with the existing dam structures, and this feeling had some support from the irrigation authorities, who were not entirely satisfied that the penstocks and gates could be fitted into the Aswan dam without changing the existing stresses in the masonry. Furthermore, problems were encountered in the design of the complex control-gate arrangement, and with the method of simultaneous operation of the four gates for each main unit. Another factor was the rising cost of steel at that time, which seemed likely to result in the cost of the penstocks and surge cham-



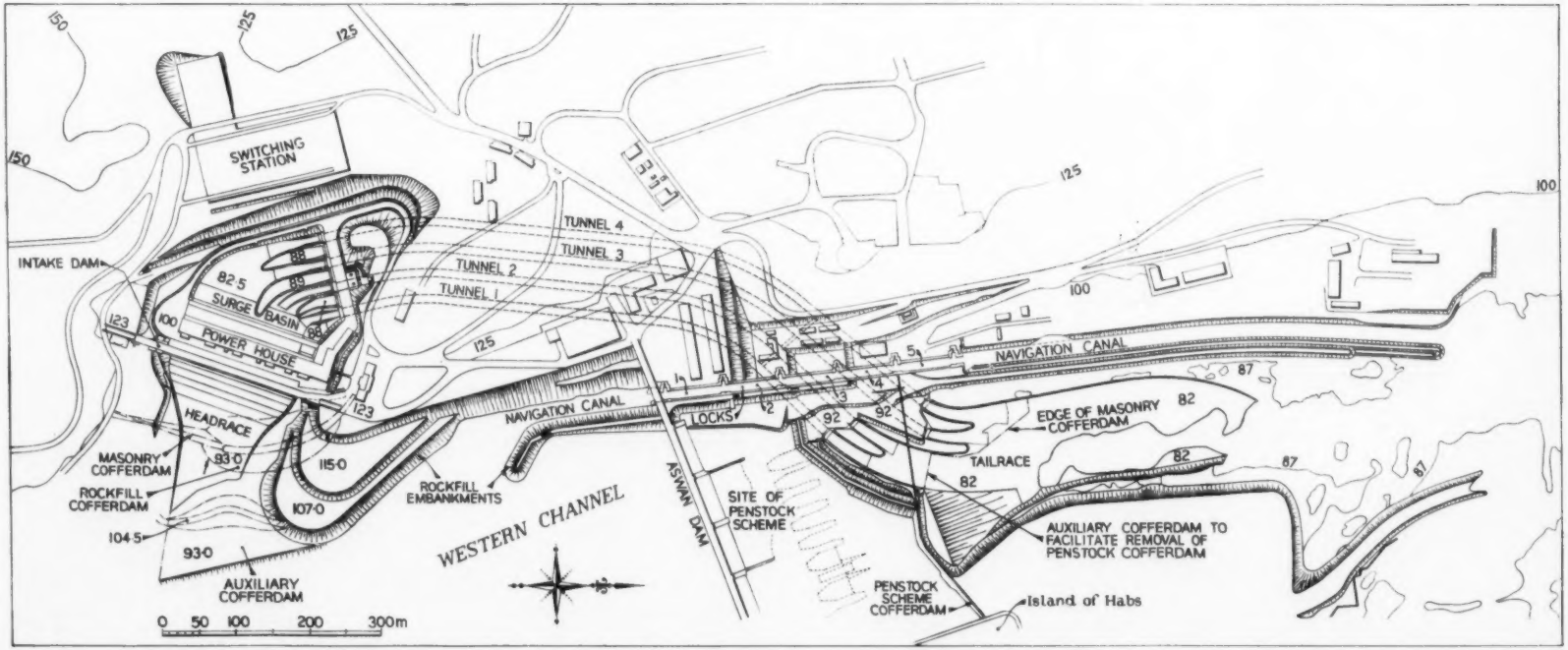


Fig. 3. Site plan of the Aswan dam hydro-electric development, together with a longitudinal section through one of the tunnels

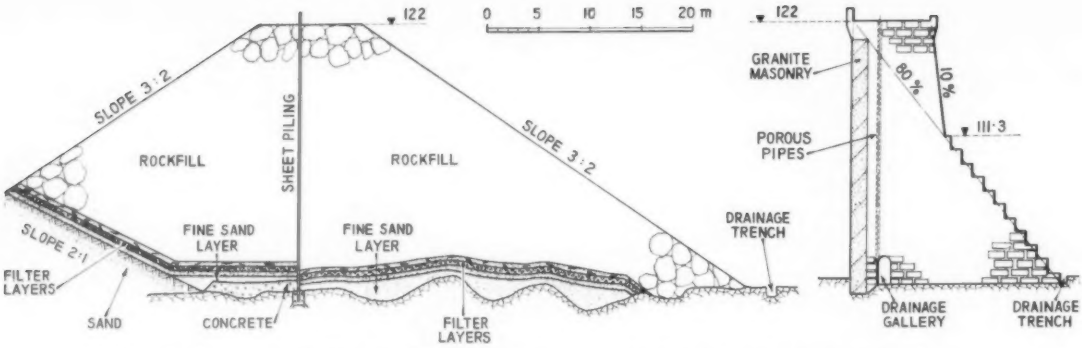


Fig. 4. Sections through rockfill and masonry portions of the upstream cofferdam

bers being far above the original estimates.

At about this time, an alternative scheme based on advanced Swedish tunnelling technique was proposed, which consisted of a separate intake structure and power station on the west bank upstream of the dam, with a tunnelled tailrace emerging downstream of the original power-station site. The changes in political leadership brought about by the Egyptian revolution resulted in a reappraisal of the whole project, and this re-examination eventually led to a decision to adopt the tunnel scheme.

Description of Revised Works

The revised scheme utilises an existing depression about 600 m upstream of the Aswan dam (see Fig. 3). A short headrace leads to an intake dam and a power station, which, of necessity, had to be designed to accommodate the original mechanical and electrical equipment. The turbines discharge into a surge basin, from which the water flows through four tailrace tunnels. These tunnels pass beneath the navigation locks and discharge into a tailrace channel, which is partly formed by the natural river bed near the western bank and which extends past the Soheil lock about 2,300 m downstream of the dam. The switching station is located to the west of the surge basin.

Basis of the Scheme

Fig. 3 gives curves of water levels and discharges for the Aswan reservoir during an average normal year. These values are dictated by the irrigation requirements and the resultant regulation of the reservoir, and it is to the large variations shown in the figure that the power development has had to conform. The average normal-year discharge from the reservoir varies between 810 m³/sec in March-April and 8,500 m³/sec in August. The reservoir elevation is held at a fairly constant value, which does not exceed 121 m, between November and April, but is allowed to fall to 99 m by July. The downstream water level also remains relatively steady from November to April, but thereafter rises with the flood to a maximum of slightly above 94 m in August.

The utilisation policy originally laid down for the penstock scheme was also applied to the tunnel scheme. The net head available throughout an average year is also shown in Fig. 2, and may be seen to vary between 33·65 m in January and 9·55 m in July, although changes in irrigation requirements sometimes cause a variation in the minimum net head. The net-head values allow for all hydraulic losses between the intake and the tailrace-tunnel portals, and these losses vary between 0·50 m at the March discharge and 1·66 m at the maximum power-station discharge of 1,480 m³/sec.

The power available naturally fluctuates considerably, and is primarily in sympathy with the widely varying head. From Fig. 2 it will be seen that the outputs range between about 300 MW at the end of May and in mid-November, and some 94 MW in July, and the main source of demand, the new ammonium-nitrate factory some 10 km away, has been specifically designed to operate in conformity with this output schedule.

It must be emphasised that the figures given in the foregoing paragraphs and in Fig. 2 refer to an average normal year. During the period 1900–57, 20 years were considered as normal, 17 years were considered high, 13 years were low, 6 years had dangerously high floods, and two years had exceptionally low floods. It will therefore be evident that the river discharges and station-output figures are somewhat conservative. The total installed capacity of the station has been related to the overall mean annual figures for the river discharge.

For the purposes of analysis, the various types of flow years are defined as follows:

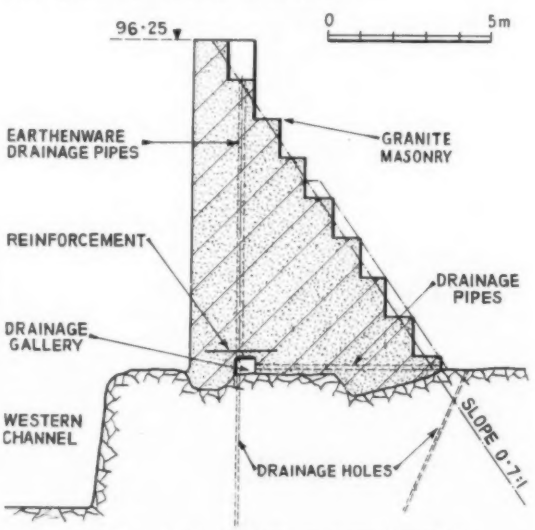


Fig. 5. Cofferdam at tunnel outfalls

Type of year	*Annual flow in millions of m^3/yr*
Exceptionally low ...	Less than 66,000
Low	66,000– 73,000
Normal	74,000– 85,000
High	86,000–100,000
Dangerously high ...	Greater than 100,000

During years of high or low flood, the output will naturally be affected, and the manner in which this will take place for relatively small variations in the flood flow is shown in Table 1. The reduction in output in high-flood years is caused by the increase in the river level downstream of the dam, and the consequent reduction in net head. In low-flood years, the reverse procedure will occur.

Geology of the Site

About three-quarters of the Aswan dam is founded on a vast granitic batholith, which has intruded into the very old crystalline basement. The remainder of the structure near the west bank of the Nile is founded on a granitic injection zone associated with the batholith, and this zone was well exposed by the excavation work for the penstock scheme.

The site of the hydro-electric works was covered by wind-blown sand overlying Nubian sandstone deposits. This sedimentary rock was laid down in the Cretaceous period, and consists of alternate sandstone and marl strata with some laterite in the lower beds. Beneath the Nubian sandstone, the basement granite was found to vary appreciably in its condition. Near the left bank of the approach channel there is a second batholith, which is confined to the north by a major fault. The tailrace tunnels pass through a predominantly sound injection zone, but between these two areas, and just downstream of the power-house site, there existed a massive mylonite dome, which was badly fissured. Associated with this fissured area was a product of chemical disintegration of the granite known as "gore," which is an arenaceous, friable material. Fortunately these fractured and decomposed rocks, which were not anticipated from the borings carried out prior to the commencement of excavation, did not extend below foundation level.

Climate at the Site

The climate in the Aswan area is typical of a desert region with high temperatures and very little rainfall. The maximum temperature recorded is 51°C and the minimum is 2°C. Over a period of 11 years, the maximum rainfall recorded in any one year was 8 mm, and the average was only 2·7 mm. However, heavy storms and rainfall are known to have occurred occasionally in the region.

The average annual relative humidity is 34%, and in the driest months the relative humidity falls frequently below 4%, and on some occasions practically to zero.

Cofferdams

The civil-engineering contract for the revised scheme was signed in May 1953, i.e., about two months before the first flood of the construction period. As can be seen from Fig. 2, this meant that only four months were available for the construction of the main upstream cofferdam, which had a crest length of 370 m and a central height from bedrock of 30 m. Work began on this structure, and also on the tunnels and general excavation, in June 1953.

Fig. 6. Panoramic view of the main cofferdam under construction

TABLE I.—TEN-DAY AVERAGES OF DISCHARGES, RESERVOIR WATER LEVELS AND OUTPUT FOR THE FLOOD PERIOD OF YEARS OF HIGH AND LOW FLOODS

Month	High-flood years			Low-flood years		
	Total river discharge	Reservoir level	Output	Total river discharge	Reservoir level	Output
	m^3/sec	m	MW	m^3/sec	m	MW
August	4,400	103·20	111	3,280	102·00	112
	6,840	105·00	107	5,200	104·10	110
	9,160	105·00	77	6,600	105·00	104
September	9,500	105·00	73	7,080	105·00	102
	9,100	105·00	77	6,840	105·00	102
	8,000	105·00	88	6,360	105·00	107
October	6,900	105·00	107	5,600	105·00	118
	5,000	105·00	128	4,000	105·00	146

and the cofferdam was completed in the October.

The southern, or left-bank, part of the cofferdam was founded on the sound granite, and was therefore constructed as a gravity-type masonry dam (see Fig. 4). For the northern wing, which overlay the zone of poor rock, the rockfill type with a central membrane of steel-sheet piling was selected. The poor rock was excavated, and the piling was then erected in a trench in the bedrock, and connected to it by means of a concrete cut-off. The joints of the piles, which were Larssen sections 3, 4B, and 10A, were sealed by caulking. In cases where splicing was required, this was done by welding. Fig. 6 shows the cofferdam under construction.

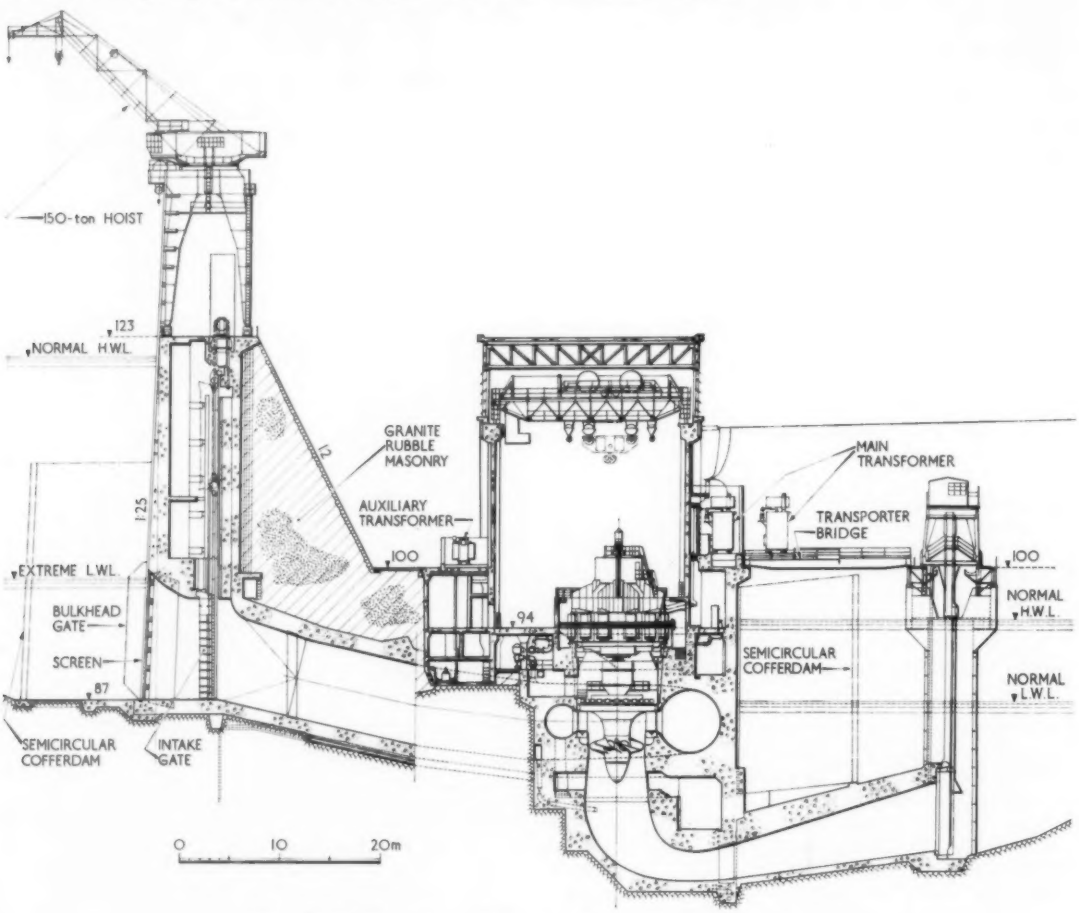


Fig. 7. Section through intake dam and power station

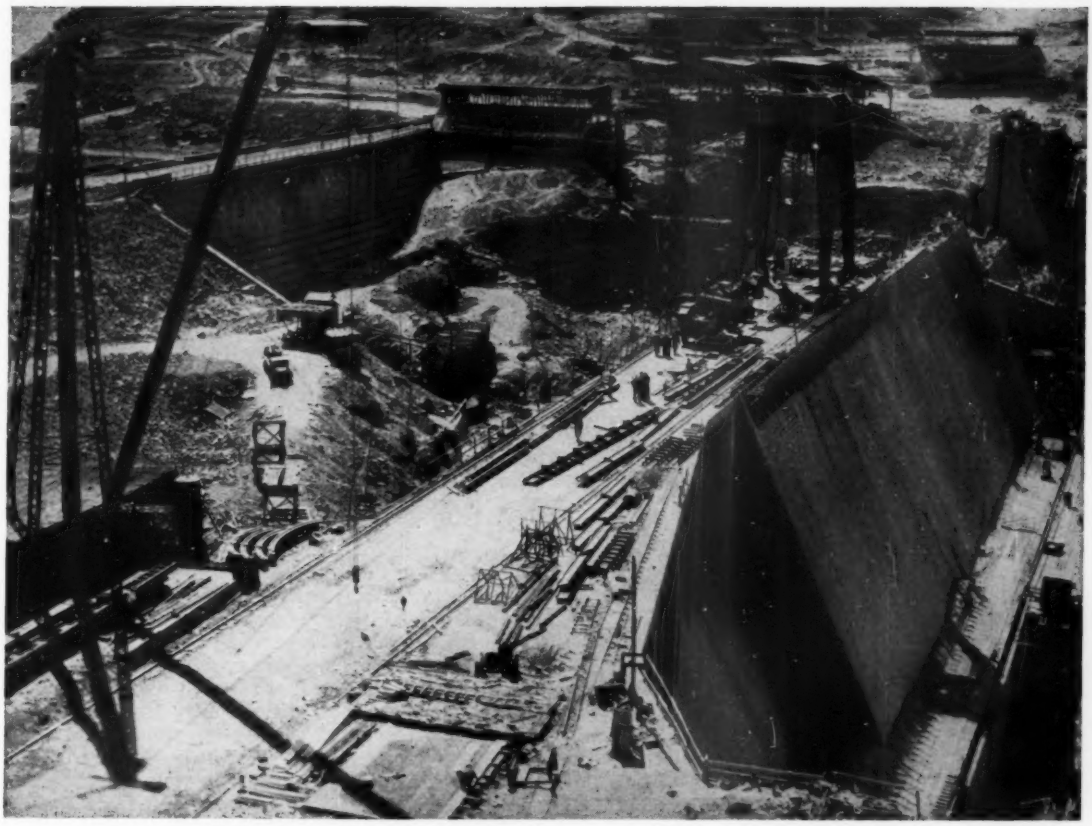


Fig. 8. View of the intake dam under construction in October, 1956

An inspection gallery was provided in the masonry section of the cofferdam, and this permitted grouting of the bedrock as the work proceeded. Grouting of the foundations under the rockfill wing was done through channels formed by covering some of the piles with steel plates, and injection at depths of up to 20 m was carried out. Drainage holes were also drilled from the inspection gallery, and vertical earthenware pipes were embedded in the masonry above the gallery. The total leakage to the construction pit amounted to 140 lit/sec during the first full storage period, and thereafter decreased to about 100 lit/sec.

A second cofferdam upstream of the main one was employed in order to facilitate the excavation of the headrace channel. This was constructed of silt dredged from the reservoir.

The cofferdam that had been constructed downstream of the Aswan dam for the penstock scheme was turned to good account by using it to protect two of the tailrace-tunnel outfalls. The other two outfalls, however, were sited downstream of the old cofferdam, and it was necessary to construct a new temporary masonry dam extending downstream from the original structure to protect these outfalls. Fig. 5 illustrates the works involved at the tunnel outfalls.

Headrace

The main factors governing the design of the short headrace were the variations in reservoir level and navigation requirements. The bed of the channel, which is at an elevation of 93·00 m, is protected by a 1-m thick layer of rock, the minimum size of which is 10 cm. In order to minimise the degree of protection required, particularly near the entrance where the excavation is in soft material, the maximum water velocity has been limited to 1·8 m/sec at a depth of 6 m below the lowest reservoir level.

Model tests indicated that a smooth inflow to the intakes and favourable navigation conditions would be obtained by extending and rounding off the river bank downstream of the entrance. This was done with rockfill in the manner shown in Fig. 3.

Intake Dam

The intake dam, which traverses the natural depression forming the site of the power station and the surge basin, contains the intakes for the seven main generating units, each having a discharge at design head and maximum efficiency of 183 m^3/sec, and the two smaller sets, each of which discharges about 35 m^3/sec. Fig. 7 shows a cross section of one of the main units from the intake dam to the surge basin.

The dam consists of an impervious-concrete front part and a supporting section of granite rubble masonry (see Fig. 8), and these are connected by closely spaced headers and horizontal reinforcement bars. The level of the masonry was kept well ahead of the concreting during construction, and this ensured that the concrete would hang on the masonry after shrinkage, thus effectively securing the stabilis-

ing load on the front part of the dam.

The main part of the dam, which has a crest level of 123·00 m and a height of 36 m, is connected to bedrock by a concrete apron, which extends 5·5 m upstream on the bottom of the headrace and also on the rock slopes forming the banks. A permanent joint, which is sealed with an asphalt string between two stainless-steel waterstops, permits horizontal movements of the structure independently of the apron. The apron also forms seatings for a semicircular steel cofferdam that can be erected at predetermined places along the upstream face of the intake structure, and which has been provided to facilitate maintenance work. The rock was grouted to a depth of about 8 m below the apron, and to about the same depth beneath the cut-offs of the wings, where the maximum depth of boring was 32 m. Drainage holes were drilled from a gallery in the dam, and these help to reduce uplift and to prevent undesirable seepage, as does the row of vertical pervious drain pipes embedded in the masonry immediately behind the concrete section.

The spacing of the main generating units is 23·5 m, which gives a minimum clearance of 0·8 m between the steel of the penstocks and spiral casings, and the transverse construction joints. By dividing each intake opening by a concrete pier, it was found to be possible to reduce the depth of excavation as well as the spans of the intake screens and gates, and at the same time to retain the 23·5 m spacing. The transitions to the circular section of the penstocks were determined as a result of model studies.

Each intake opening is provided with a screen having a gross area corresponding to a maximum allowable water velocity of 0·8 m/sec, and all the screens are of the same gross width. The spacing of the screen bars does not exceed 215 cm for the main units and 10 cm for the small units. The bars are supported by horizontal wood-filled steel beams, spanning between heavy upright steel sections, which are embedded in the dam face and extend to the dam crest. These upright sections also support rails for the two bulkhead gates, which are provided for the temporary closure of the intake openings. The screens have been designed to resist a differential head of 8·5 m with a maximum allowable stress of 1,700 kg/cm². At a differential head of 2 m an alarm system will give warning that the screens require cleaning.

A combined jib-and-portal crane is mounted on rails on the dam crest. The lifting capacity of the main hoist for the bulkhead gates is 150 tons (see Fig. 7), and that of the crab travelling on the portal structure, which is intended for handling the gates and roller carriages, is 40 tons. The jib for handling the cofferdam sections has a capacity of 8 tons, and a separate hoist block of 7·5 tons capacity is also provided.

The bulkhead gates are of the fixed-wheel type, and can be lowered with a turbine at runaway speed and raised under no-flow conditions. The main intake gates are of the free-roller-train type designed for gravity closure under all conditions, and are operated by oil-pressure servomotors. The operating mechanism allows the roller train to be lifted clear of the waterway, and the lower edge of the gate leaf to be raised to about 21 m above the sill level of 87·00 m. Under the existing irrigation programme, the gate will be accessible at this level for maintenance work during at least three months in the year. In an emergency, the gates close automatically in about 40 sec, and air is then sucked into the penstocks through vents behind the gate wells.

The maintenance cofferdam consists of a number of arches of a welded I-section, placed one on top of another. When erected, the arches form a half cylinder about 25 m in height in front of the intakes. The cofferdam units have been designed for use against either the upstream face of the intake dam or the downstream wall of the power station, and also for the tailrace-tunnel intakes and outfalls.

Tailrace Tunnels

The four tailrace tunnels each have a cross-sectional area of 150 m², and are spaced at distances of 35 m between centres. The lengths vary between 727 and 904 m, and their location was chosen in order to avoid heavy blasting in the vicinity of the main dam and locks. A bend to the west in the tunnel alignment keeps them clear of the western dam abutment, and a minimum cover of 15 m has been allowed beneath the locks. The portals at the tunnel intakes and outfalls (see Fig. 10) are provided with vertical rails

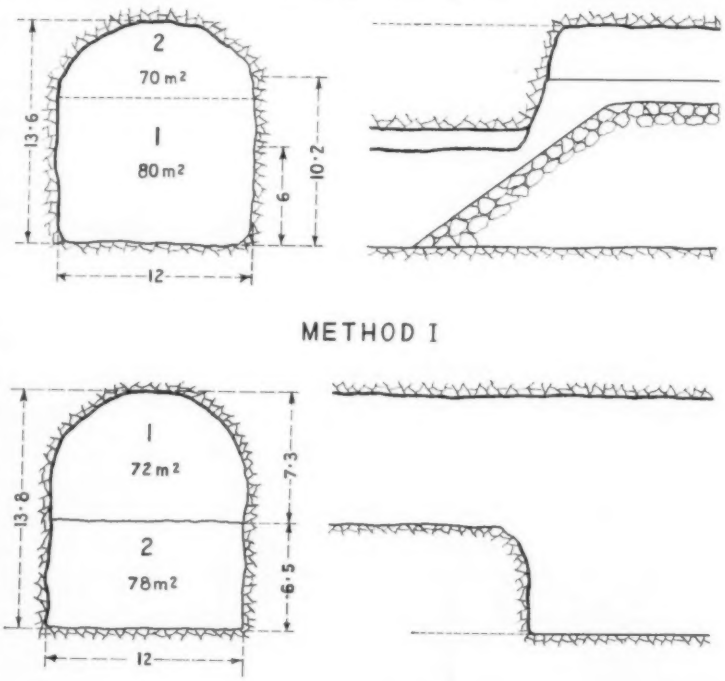


Fig. 9. Alternative methods of tunnelling

Fig. 10. Tunnel inlets Nos. 3 and 4 during filling in the summer of 1959

for the erection of the dewatering cofferdams.

The quality of the granite was mainly fair, but where zones of poor rock did occur prefabricated steel arches were used for temporary support. These consisted of curved I-sections at 2-m spacings, and they later served as supports for the steel shuttering used for permanent concrete roof arches, which in some cases were extended to the tunnel inverts. About 580 m of the total tunnel length of 3,308 m required concrete strengthening, and 254 m of this total was located near the outlets. In zones of rock of intermediate quality, deformed steel anchoring bars or Perfo bolts were employed.

The tunnels were all driven from their downstream ends, and the contract stipulated two main methods of driving, which depended on the quality of the rock encountered, and these methods are illustrated in Fig. 10. Method I, which was intended to be the normal one for use in stable rock, consisted of first excavating the bottom part of the tunnel, which had a cross-sectional area of 80 m². The upper face was then driven, with the top and slope of the excavated rock being used as a working platform. Where bad rock was encountered, the contractor had the right to change to method II, which consisted of working at an upper face of 72 m² in cross-sectional area, thus leaving a bench to be excavated later. The second method permitted the execution of roof strengthening before the full cross section was excavated. The changes from one method to another were paid extra, and it was left to the consulting engineers to decide when the quality of the rock required these changes.

In extremely bad rock a third method, using small pilot tunnels, was employed. This was used only for short distances at the inlets and outlets, and for a few metres where the tunnels passed through fault zones. The total length driven using this method was 171 m, whereas method II was employed for 2,145 m and method I for 992 m. In all, 13 changes of method were required.

Work proceeded simultaneously on the four tunnels, and the ordinary equipment used consisted of Atlas hammer drills type RH656 with airlegs, Ruston Bucyrus 33-RB excavators, and 15-ton Willème trucks. The tunnel works, including approaches in open cut and strengthening works, were completed in about 34 months.

In the flood season of 1960, when the station was in partial operation but on very low load, major silting occurred near the outfalls of two of the tunnels. This incident, and the clearance operations, will be described in detail in a future issue of WATER POWER.

Tailrace Channel

The tailrace channel curves away from the tunnel outfalls to form an extension of the Western Channel. The elevation of the channel bed, in which the maximum velocity will be 1·7 m/sec, is 82·00 m and its base width is 145 m.

Excavation for the tailrace comprised some 300,000 m³ of rock and 320,000 m³ of silty overburden, and this work was carried out only during low-water periods. At times of flood the area was inundated by using a filling pipe through the main downstream cofferdam.

Some excavation was also carried out in the river bed near Soheil lock, about 2,000 m downstream of the tunnel outlets, and this has resulted in an increase in head at Aswan of 1·7 m during the period December–July.

(To be continued)

International-River-Basin Development

A seminar on the development and administration of international river basins was held in Vancouver recently under the auspices of the United Nations

THE fact that political boundary lines seldom coincide with watersheds has always created difficulties in the development of water resources. The problem is particularly serious, however, in cases where river basins are shared by more than one nation. Across the world today there are about 70 river basins which are traversed by international boundary lines. As new nations are established the number of international river basins will grow and the difficulties of development will correspondingly increase. What problems are likely to arise and how they might be solved were questions posed in the Seminar on the Development and Administration of the International River Basin held under United Nations sponsorship at the University of British Columbia recently.

Although many of the world's international river basins possess huge hydro-electric power potentials and many of them could be developed to provide irrigation, flood control, and other services, only a few of these basins have been developed so far. The main reasons stem either from the fact that the possibilities have yet to be recognised or from the institutional, technical, or economic impediments to development. The objective of the Seminar was to isolate some of the most important of these impediments and to suggest means by which they might be overcome. To this end six of the world's major river basins were studied in some detail, namely, the Columbia, Rio Grande, St. Lawrence, Danube, Indus, and Mekong. The discussions revealed four major deficiencies that impede the planning and development of international river basins: (1) Lack of basic data, 2) lack of mutually acceptable standards of evaluation and techniques of analysis, (3) lack of broadly applicable principles of international law, and (4) lack of appropriate administrative machinery and skilled personnel to undertake the planning and development.

Basic Data

The provision of adequate basic data is a fundamental requirement in the planning and development of all river basins, but in international river basins this requirement has particular importance. Before the nations involved can determine what the possibilities of development are they must come to agreement regarding what data are required, how they shall be collected and by whom, and in what form they shall be published. It seems that one of the greatest difficulties in achieving such agreements is the lack of standardisation of terminology and of methods of collecting, processing and publishing data. Much progress has been made towards this end —particularly through the United Nations and its associated organisations—but it is clear that much remains to be done.

The delegates recommended that a committee should be established to draw up a standard terminology relating to basic data required for international-river-basin development. It is also apparent that a survey is required to determine what data are available relating to the international river basins across the world. The delegates reccommended that such a survey should be undertaken. They recommended further that nations which share international river basins should be encouraged to collect at least minimal data with respect to these basins.

Two broad groups of data are required for river-basin planning and development: physical data and socio-economic data. There are substantial differences of opinion as to the number of each type of data required, and as to the stage at which they should be collected. There was general agreement that the physical data should be gathered from the outset. Usually the socio-economic data can be gathered at a subsequent stage in the planning.

Where, however, the urgency for development is especially great, the two types of data should be gathered concurrently. Whatever the case, planners must ensure that due regard is accorded to economic requirements as well as to physical possibilities for development. Unless this is done projects may be under—or over-designed and water resources not used to their best advantage.

One of the major obstacles to river-basin planning is the fact that certain data are not available on a river-basin basis. This is especially the case with socio-economic data. The delegates recommended that governments should give attention to this problem and should be encouraged to take steps to correct the deficiency, especially where international river basins are involved.

Economic Evaluation

The degree to which countries sharing an international river basin are willing to co-operate in development depends upon how such development will affect their individual economic welfare. Each country will have to weigh the gains and costs which would result from co-operative action against the gains and costs of providing similar services on a unilateral basis. To this end, the nations involved must agree to mutually acceptable standards of evaluation. They must agree as to which benefits and costs should be taken into account, and how they should be measured. They must also decide upon a basis for allocating the benefits and costs of the co-operative venture among the participating nations. Disagreement on these matters has held up the development of several international river basins. A notable case in point is the Columbia River basin, where Canada and the United States were involved in lengthy negotiations to develop mutually acceptable formulae for determining and allocating downstream benefits from upstream storage.

Economic evalution should be distinguished from financial evaluation. The former is concerned with

weighing up the broad effects of the projects on the economic welfare of the nation. The latter, however, is usually concerned only with the problems of finding funds for development and the reimbursement of these funds. The discussions revealed that in many cases projects are subjected only to tests of financial feasibility and that economic evaluations are sometimes not carried out at all. It is clear, however, that if the nations participating in a co-operative venture wish to be sure that they are making the best use of their water resources, the overall effects on the economic welfare of the nation need to be taken into account.

International Law

While the success of a plan for international-river-basin development depends in the long run on co-operation and goodwill, it is obvious that many conflicting claims have to be balanced and reconciled. Some of the issues that are raised are not adequately covered by existing international law. For some years lawyers have been trying to draw up a set of principles that will have broad application with respect to the development of international rivers. At the recent meeting of the International Law Association in New York a number of "Agreed Principles" were drawn up. These principles were discussed at the Seminar and opinions varied as to their usefulness. There was general agreement that the doctrine of equitable apportionment should guide law-makers in their decisions. Many of the delegates stressed the need for the closest possible collaboration between the lawyer and the technical adviser in drawing up principles of law relating to river-basin development.

The treaty is generally accepted as the most satisfactory way of dealing with international water problems. Attempts to force solutions by appeals to international law are generally unsatisfactory in that the confirmation of the right of one state to take international action often results in development that is less beneficial than would have been possible with co-operative action.

Administrative Organisation

The development of international river basins requires the establishment of agencies to carry out the necessary negotiations, investigations, planning, construction and operation of projects. Various types of administrative structure have evolved to perform these functions, each one appropriate to a particular set of circumstances. Some useful generalisations, are, however, possible and pertinent.

Seldom is one agency set up to carry out all the required functions. While new agencies are sometimes set up to handle one or more of the functions, it is more often the case that the functions of existing agencies are extended to encompass the functions relating to international projects. Such has been the case in the investigation and planning of the Columbia River Treaty projects.

Whatever the type of administrative structure established, co-ordination and co-operation must be the keynotes. Each agency concerned with the development must be sensitive to the plans and policies of the other agencies responsible for water development in the basin. The need for such co-ordination and co-operation is especially great in cases such as the Mekong River basin where the development of the main stem has been planned by four nations. Development of the tributaries, however, is in the hands of the individual nations through which these tributaries pass. Since the development of the tributaries will have profound effects on the projects proposed for development on the main stem, the utmost co-ordination and co-operation will be required.

Of all the deficiencies in the planning of international river basins, that of the lack of skilled personnel is by far the most serious. There is a great dearth of skilled policy-makers, engineer-economists, hydrologist-ecologists, and planners and operators who can formulate, negotiate, and realise concrete proposals for development. The training of skilled personnel seemed to the delegates the most urgent problem requiring solution. Interchange of personnel between countries, training schemes, and conferences on common problems were some of the possibilities suggested for solving the problem.

Perhaps the most important lesson to be learned from the discussions at the Seminar was the fact that it is possible to segregate the negotiation of problems relating to the development of international river basins from other problems of international concern. Much can be learned from examining the experience of the various nations across the world in developing river basins. The forthcoming Transactions of the Seminar will provide a valuable guide to all those concerned with the development of international river basins.

Loading and Haulage Equipment for Cruachan

Edmund Nuttall, Sons & Co. (London) Limited, who were recently awarded the contract for the construction of the Cruachan underground pumped-storage power station, have chosen Eimco loading and haulage equipment for this work. This 400-MW pumped-storage project is part of the North of Scotland Hydro-Electric Board's Loch Awe scheme, which includes conventional hydro-electric stations at Nant and Inverawe. James Williamson & Partners of Glasgow are the civil engineering consultants.

The Eimco machines ordered for the scheme include a Model 105 1½ cu-yard tractor excavator (powered by a 143-h.p. diesel engine) and two Model 622 crawler-mounted rocker shovels which are compressed-air powered and can be used for direct loading or alternatively in conjunction with 32-ft³-capacity rear-mounted bottom-discharge hoppers for transporting the material over a distance. Three Model 850 Eimco dump trucks have also been acquired by Edmund Nuttall for this major contract on account of their maneouvrability in the limited turning space available in the tunnels.

The Cruachan scheme involves excavation of approximately 200,000 cu yards of granite, which includes an underground machinery hall, 320 ft in length, 75 ft in width and with an arch roof about 120 ft above lowest floor level; underground transformer, control and switchgear rooms, a 1,050-ft 13-ft diameter combined ventilating and cable shaft; a 3,200-ft 23-ft-diameter tunnel connecting the power station with Loch Awe; and two inclined shafts each 1,700 ft in length and for the greater part of their length 15 ft in diameter.

Watershed Resource Value*

The author submits that the associated development of fish and power in a watershed is a practical proposition. He discusses reservoir management, fish rearing and control, and passage past hydro-electric works, and shows how the fish resources of a river can be planned and commercially assessed

By VAL GWYTHER, M.E.I.C., F.ASCE., P.Eng.†

THE necessity to conserve the salmon resource in the many watersheds of British Columbia which these fish inhabit, or could inhabit, has retarded the development of other resources, primarily hydro-electric power. This is due only to our present inability to ensure present production of salmon by natural spawning and rearing in fresh water. This condition exists today even though we are unable to affix a definite yearly value to salmon production due to variations in climate and other influences of nature. To conserve and increase production of the salmon resource in a watershed from which we wish to obtain the benefits of power, we must provide means to protect these fish in their fresh water life. This paper discusses matters vital to proper understanding of salmon production in large quantities jointly with power. With this joint development of watershed value, where large lake areas exist or are impounded, the value of the salmon resource may well exceed that of power.

Salmon Species—Survival—Management

Commercial production relies on five species of salmon: sockeye, pinks, chums, cohoe, and spring. The first three species, throughout their free swimming lives are dependent mostly on plankton for food while the last two species as they increase in size become fish eaters. The cohoe and springs are the main sporting fish while the steelhead, a trout, is valuable in both sports and commercial fishery in the sea and sports fishery in fresh water.

In this paper I have used the sockeye species as an example as they contribute the greatest value to our commercial fishery and they require added protection in rearing areas.

In natural spawning, a tremendous loss of life is caused by: under and over seeding of spawning areas; incomplete spawning of females; inefficient fertilisation of eggs; flash floods; varying river levels caused by fluctuation of power plants; temperatures too warm or too cold; pollution; drying up of river beds; sedimentation; lack of food; predatory birds, animals and fishes; the inability of salmon to bury their eggs; frost; insanitary conditions in nests during incubation; and delays in passing dams which have not been properly designed for fish passage. With these heavy losses, if one-tenth of one per cent of the eggs live to grow and return as adults, the runs are maintained.

By artificial fertilisation and incubation in hatcheries, successful means have been developed in bringing to life 80 to 90% of the salmon eggs produced by all five species. In hatcheries, eggs are taken from salmon ready to spawn and placed in incubation trays. From this point on they are kept free of all natural hazards until they become free swimming fry. With properly prepared rearing areas they are protected from predators until they migrate to the sea. We then may have a survival rate of 80% of all eggs prior to migration from rearing areas. Again, if we are able to eliminate predatory fish in migration routes to the sea, at least in part, we are able to reduce mortality.

The predatory fish problem is one of the major problems that must be solved. We are advised, "It has been shown that after sockeye fry are liberated in Cultus Lake a mortality of from 94 to 97% occurs. This, it may be presupposed, exists irrespective of whether the fry are reared naturally or in hatcheries, and therefore presents, perhaps, the most urgent problem facing fish culturists[2]." This is in the rearing areas.

In migrating streams and rivers in a 10-mile reach of Minto Creek we are advised. "Stream mortalities on various lots of 500 to 585,000 fingerlings planted under five months of age ran from 87·5 to 98·2%. Stream losses on lots from 3,000 to 53,000 planted at six months of age were 74 to 83%. At nine months of age losses in plantings of 3,000 to 33,000 were 53 to 67%. At 12 months plantings of 5,000 to 70,000 showed stream losses of 17 to 43%, while plantings of 14-month-old fish in two lots of 30,000 and 98,000 showed only 16 and 12 percentage respectively. While stream factor loss was far less on 14-month-old planted fish, it was evident from high marine mortality, that young silvers (cohoe) held that long, were unable to cope with conditions in salt water. Thus on the face of present knowledge ultra long rearing term is not the answer[3]."

If we investigate the life history of those species of fish which are predators on salmon, either by devouring the small fishes or devouring the food in the streams, rivers and rearing areas that could support salmon, we find that some of the species migrate from the sea to fresh water spawning grounds and some are totally fresh-water fish. However the latter migrate from the lakes to incoming streams to spawn. These species then all appear to migrate, deposit their eggs in the same gravels as do salmon and the small migrants return to the sea or lakes to continue their lives. There may be some species whose total life is spent in lakes, in which cases lake poisoning may be necessary. It appears that control of all migrating predatory fishes can be accomplished if we are able to extract these fishes in the migration routes.

Our present policy of propagation of salmon by natural spawning, in the numerous watersheds of

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British Columbia, from which the salmon harvest is produced, is certainly not beneficial to the industry as yield is progressively reducing. This was realised before the turn of the century when a hatchery programme was commenced. A number of hatcheries were built in later years, but production did not appear to be increasing. In 1936 all hatcheries were closed after a study was made as to the respective indices of incubation in the three methods of propagation, namely natural spawning, planting of free-swimming fry (hatcheries) and planting of eyed eggs.

The results of this investigation are available to us[4] and the conclusions and their interpretation are of extreme importance in our proper understanding of present policy[15-17] in sockeye salmon propagation, and therefore must be reviewed.

Conclusions 1, 2 and 3 show the relative efficiencies of natural spawning, hatcheries and plantings of eyed eggs. Conclusion 4 is: "During the year's residence in the lake from 94 to 97% of the fry liberated therein perish. The loss has been attributed largely to predatory fish—squaw fish, char, trout and sculpins. Tests are now being undertaken to determine the benefits accruing from destruction of predators." The conclusions continue: "The above data may appear to show an appreciable benefit to be obtained from artificial propagation. On the contrary, however, due consideration of ranges of variation in percentages of efficiency for each of the three methods indicates that the differences which seem to exist between the methods are not significant. They do not portray any distinct advantage for any one of the three methods tested.

On the basis, therefore, of the above results, it may be concluded that in an area such as Cultus Lake where the natural run of sockeye occurs with reasonable expectancy of successful spawning, artificial spawning for the purposes of continuing the run to that area is unnecessary, and if producing any additional results over natural spawning, these would not appear to be in any way commensurate with the cost."

Conclusions 1, 2 and 3 indicate that there is a slight increase in production of fingerlings both in hatchery propagation and artificial spawning in the amount of perhaps only 75%. If higher efficiencies had been obtained in fertilisation of eggs, in natural spawning by higher percentages of returning males, this increase by artificial means may even be nullified. Conclusion 4 is the most important of the bulletin, and, in my opinion, limits the validity of conclusions 1, 2 and 3. Greater success in artificial spawning would have been obtained if predator control had been carried out.

What then do these conclusions mean? Is the increase recorded in hatchery propagation based on 4·5% of survival? Records of escapement returns of later years appear to indicate this meaning. Or does it mean that as greater quantities of hatchery-produced fish were placed in the lake the predators were better fed, grew larger and fatter and more numerous and continued to devour the salmon fingerlings in quantity, at a rate per unit of fish which is slightly less than that in natural spawning? With this prime factor of destruction of salmon fingerlings by predators, have we any indication of the comparable indices of production in the various methods of propagation?

Hatcheries were closed at the end of 1936. The International Pacific Salmon Fisheries Commission report results from 1939 to date[5]. The returning races of 1935 and 1936, four years later, which were assisted by hatchery propagation report escapement to Cultus Lake in quantities of 73,189 and 74,121 respectively. All future reports of these two races up to 1956, after they received no assistance from hatcheries, varies from 8,898 to 26,000 or an average of about 15,000 adults. This then is an increase in escapement of about 500% when runs were assisted by hatcheries even though 95·5% of all fry liberated in the lake were devoured by predators.

Certainly then, our present appreciation of efficiency in the various methods of propagation requires adjustment.

Reservoir Management

The quality of water that is discharged from impounded reservoirs or natural lakes is of primary importance to survival of salmon during migration and their existence in river channels. Unsatisfactory control of reservoirs in all seasons tends to retard migration of adults and pollute river channels below the reservoir. In all reservoirs stratification exists with depth in all items of water quality. However, thermal stratification has a tendency to alter chemical and physical quality due to seasonal variations of climate. Alterations in water quality will also occur due to temperature, quality and quantity of the inflowing streams and rivers and the quantity and depth release of discharge water from the reservoir. In such items as turbidity, colour, odour, biochemical oxygen demand (B.O.D.), dissolved oxygen, free carbon dioxide and nitrogen are concerned, those waters near the surface are more beneficial than those of some depth. Surface waters may, however, be too high in dissolved oxygen and temperature which is detrimental.

As far as chemical quality is concerned in these waters, the decay of organic matter tends to use the dissolved oxygen and form carbon dioxide. This biochemical oxygen demand is defined by the American Public Health Association as the oxygen in parts per million (p.p.m.) required during stabilisation of the decomposed organic matter by acrobic bacterial action. Complete stabilisation requires extended periods of time; therefore for practical indices B.O.D. requirement for a five-day period at 20°C is used.

While this decay of organic matter is using up dissolved oxygen the small plant life of the water (algae, water plants, diatoms, etc), by photosynthesis, takes in carbon dioxide and gives out oxygen. As an example of the variations of B.O.D. dissolved oxygen and carbon dioxide with reservoir depth, at the bottom of a 77 ft reservoir, decomposition had used up all dissolved oxygen and had put 12·2 p.p.m. of carbon dioxide into the water. At 40 ft the carbon dioxide was 8·5 p.p.m. and dissolved oxygen had risen to 31% of saturation (too low for fish life). At 20 ft the carbon dioxide had diminished to 1·5 p.p.m. and the dissolved oxygen had risen to 90% of saturation (satisfactory for fish). At the surface, carbon dioxide had decreased to 0·5 p.p.m. while the dissolved oxygen had increased 6% beyond the saturation point (oxygen high for fish). The water at the surface being slightly supersaturated with dissolved oxygen (Fig. 1).

Obviously since the process of photosynthesis is dependent on light there are differences in the

amount of oxygen in a lake or reservoir in the day and in the night or even in sunny or cloudy days. There is also some retardation in reservoirs carrying heavy sediment, as light does not penetrate this water as readily as it does clear water.

Both decay and plant growth are faster in warm weather than in cold, but even in winter under the ice both processes are taking place, although at much slower rates than during summer conditions[6].

With regard to physical behaviour, the maximum density (specific gravity) of a unit of volume of pure (distilled) water is at a temperature of 4°C. As the temperature decreases the density progressively decreases, or it occupies greater volume, until it reaches 0°C, where it changes its physical state from liquid to solid, with abstraction of heat. There is an increase in volume of water at 0°C to ice at 0°C. As the temperature lowers beyond this point the ice increases in density. Again as the temperature of water rises from 4°C to 100°C there is a progressive decrease in density. With acceptance of heat at 100°C the water changes to steam.

The acceptance of hardness by water whether it be in solution or suspension, will increase the density of water. This density will be increased in proportion to the amount of hardness and also in relation to its chemical composition as designated by its molecular weight, volumes being the same.

The erosion of the geological formations by precipitation and its related forces provides inorganic sediment and the decay of vegetable growth provides organic sediment. These two types of sediment have different specific gravities which on the average may be in the ratio of about 2·65 to 1·2[7].

Water has the ability to transport sediment in suspension and this ability varies as the 2·56th power of the velocity[7]. Water also has the ability of moving sediment along the bottom of a relatively shallow water course, and this ability appears to be in the relationship of the sixth power of the bottom velocity[7]. With climatic variations in precipitation and temperature we are provided with varying velocities in river discharge with its accompanying ability to transport larger particle size and in greater quantity.

Each particle of suspended sediment will settle in a still reservoir of pure water due to its higher density, and the inorganic sediment will settle out at a more rapid pace than organic sediment, particle size being the same. As an example a particle of 1 mm diameter in 10°C water has a settling velocity of 100 mm/sec for inorganic material and 12 mm for organic matter. Continuing down the scale in particle size, a particle with a diameter of 0·001 mm will settle out at a velocity rate of 0·000,015 mm/sec for inorganic material and 0·000,00084 for its equivalent in particle size of organic material[8]. These settling velocities in fine particle-size materials are very small; they will be decreased by water hardness and particles may be retained in suspension with vertical oscillations of water due to temperatures.

These then, with effects due to chemical changes in the reservoir, local currents and wave motion, are the influences which nature provides and which must prevail in any reservoir.

If we examine a reservoir in the interior of British Columbia, with the varying temperatures of inflow water and atmosphere we will readily appreciate that in winter months the surface water is colder than the lower waters and the opposite occurs in the summer period. Then there is a complete turnover of the surface strata twice per year. In this turnover, waters of maximum density pass to the lower reservoir and may remain there for generations. The same occurs in coastal areas provided at some time the atmosphere is lower than 4°C.

With heavy inflow, gradually building to heavy outflow, as lake storage is developed, we may have some disturbance of these lower waters, especially in relatively shallow reservoirs as density currents will form due to temperature difference.

Then in the interior of British Columbia during the winter months we may expect a thermocline from the bottom of the ice to some depth varying from 0°C to 4°C, and the remaining depth of 4° water. In summer, during heavy discharge, we may expect a pool of warm water floating in the density current and underlain by the dead waters at 4°C. The coastal area is somewhat the same except that the density currents occur in the winter months due to heavy discharges, and these may travel on the surface at this time.

In reservoir management there are some other influences which we must consider. These bodies of water, in their ability to retain water for a period of time, not only level out variations of hardness but allow purification of these waters. We then can expect larger variations at the upstream end of the reservoir and increased hardness with depth.

How then are we to manage the discharges from power reservoirs, whether it be turbine drawoff or flood discharge, to ensure satisfactory quality at all times and all stages of operation throughout the year accompanied by the drawdown of storage? Obviously we must regulate the discharges from those zones of reservoir depth that are satisfactory for fish. In order to accomplish this we must ensure a stable reservoir condition from which we are able to extract known water.

In this appreciation we cannot use the bottom dead waters at any time of the year due to lack of oxygen and to pollution, and we should not use surface waters as they are supersaturated with oxygen and may have unsatisfactory temperatures at some times of the year. We then must abstract all waters from below the surface to a point of some depth above the relatively dead waters in the reservoir bottom. It is beneficial to be able to mix these strata for satisfactory fish migration.

Rearing Areas

How must we approach this problem of economic production in the salmon species in quantity with assurance that other benefit resource value of the watershed can be jointly obtained at the same time or some future time? Alternatively, if other resource values are developed prior to salmon, will this potential resource value be retained for future development?

Our present index of the value of the salmon resource, namely the ability to incubate salmon by natural spawning and rearing in bodies of water in their natural state is far removed from the potential value from production in these species.

The potential value of salmon production in any watershed is only dictated by the rearing capacity and what may be accomplished to improve these rearing areas for optimum yield. Spawning of salmon and the incubation of eggs, whatever method is used, must

keep pace with the ability to produce in rearing areas. Furthermore incubation must keep pace with productivity in rearing areas as we continue to increase the fertility of these areas and reduce predation losses.

We are advised that: "Fish of all kinds respond tremendously within their proper environment to the right kind of fertiliser in the water whether it is organic or inorganic. The reason is simple. The fertiliser stimulates growth of vegetable plankton. This produces more food for tiny free-swimming plankton and small crustacea which graze upon the vegetable matter. With adequate food and favourable water temperature, animal plankton multiplies phenomenally. Larger insect larvae and nymphs, as well as fish fry, feed on the lesser plankton and thrive. The fingerlings and adults gorge on both larger inhabitants as well as on the myriads of amphipods, those many-legged little creatures which swarm the waters of good fish producing areas. Break this chain of production anywhere along the line, or overload it, and the water can become barren of desirable fish[9]."

"Mineral requirements for the continued survival of fish in both fresh and salt water include a minimum of 50 p.p.m. of calcium and traces of phosphorus, nitrogen, iodine, sulphur, cobalt and magnesium. Other minerals may be desirable. Of great importance, therefore, to good fish growth is the quality of water itself, which must contain the desired elements to foster the growth of all links in the vegetable and animal chain essential to desirable productivity. If these elements are not available in natural water selected for a production programme then means must be found of introducing them artificially to achieve best results[10]."

Every acre foot of water in our lakes of British Columbia contains some soluble hardness which is dissolved by water as precipitation erodes and transports the geological formations in each and every watershed. This hardness through the chain of production is the food of small salmon fish. The food which exists under an acre of lake surface, in that zone of depth which fish are able to inhabit, is the index of fertility of the area. As hardness increases and oxygen decreases with depth (Fig. 1) small fishes are unable to obtain the benefits of the majority of food which is acquired by water during erosion of the watershed. This very large storage of dissolved hardness at lower depths is a potential storage for fertilisation of the upper zone which the fish occupy.

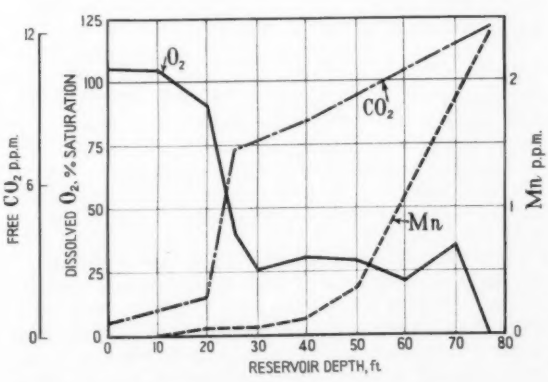

Fig. 1. Reservoir quality with depth (compiled from Table 26, p. 69—"Water Treatment," Eskel Nordel)

The hardness of our waters varies considerably depending on the geological formations of the watersheds and the ability of run-off water to dissolve chemical ingredients from these formations. The waters that are collected in and discharged from the Coast Range have a tendency to be slightly acid and are low in calcium hardness. As we proceed easterly in the Cascades they carry higher quantities of dissolved solids. Those waters which are collected and flow through the Rocky Mountains are relatively high in dissolved hardness and of a calcium base.

There is also a variation in water hardness (p.p.m.) due to seasonal climate, especially in those streams and rivers which have no regulation of flow by lakes. These lake reservoirs tend to average out the variations in water quality between inflow and outflow water.

This then means that the lakes in the interior of British Columbia have greater capacities for rearing fish per acre foot than those in the coastal areas and probably in proportion to the dissolved solids they contain, which water plants require and are able to assimilate.

In natural conditions, adult salmon migrate upstream, deposit their eggs, and die. In the nutriments derived from the decaying of these carcasses, the waters of the streams, rivers, and lakes are fertilised prior to the removal of adult salmon by the industry at sea. In our present management of taking 80% of adults at sea and allowing 20% to escape, we are interfering with nature's method of fertilisation and thereby depleting the rearing areas in their ability to produce fish in size and quantity. Regardless of how inefficient nature's method of fertilisation may be, there is little doubt that with this practice over a period of years the rearing areas will be seriously affected and we will of necessity have to supply food artificially to maintain production. Of course, this is dependent on the ability of watershed run-off to acquire dissolved hardness.

The present practice in the planting of cohoe fry in predator-free lakes of western Washington, which is relative to our coastal area in fertility, is 5,000 fry to the acre of surface area[11], without feeding. As these fish, at the migration to sea age of about one year may run about 45 to the pound, this then is a rate of planting of 111 lb fish to the acre, and appears conservative.

As an indication of rearing capacity increase with intensive feeding such as now practised in hatchery pools, we are advised that the capacity of these pools is 22,000 lb of fish per surface acre with intensive feeding, as against 200 lb of fish per acre in open lakes without feeding[12]. This then is the ratio of 990,000 to 9,000 fish or an increase that can be obtained by intensive feeding of 110 times. Then any feeding in our predator-free lakes above that which may be necessary to maintain present fertility will increase the capabilities of the lake in producing fish.

The above capacities are predicated on predator-free lakes, which prior to preparation for rearing of salmon in quantity, or even in our present policy of management, are heavily inhabited with predatory fish. These predators migrate from the sea, where they can be abstracted in the migration routes. Some of these predators migrate from the lakes to incoming streams to spawn and they may be removed during this migration. We may, however, have some species that remain in the lakes for their entire life and these

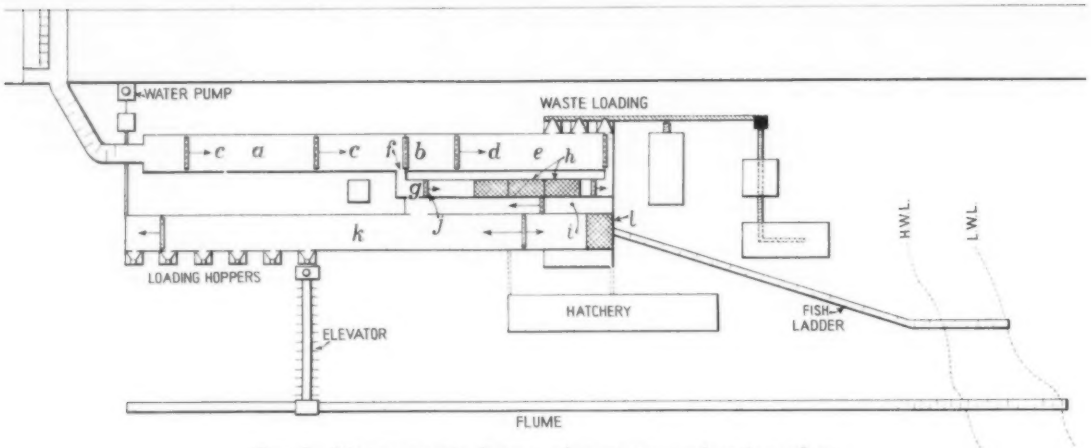

Fig. 2. Diagrammatic layout of upstream migration plant

will have to be removed by poisoning of the lake waters.

We then have a definite index of value, namely per acre of rearing capacity, which we are able to add to any overall watershed value for the salmon resource. There appears no other index which we can use in assessing this potential value with assurance in yearly production.

Upstream Migration

Satisfactory facilities for upstream adult migration require the concentration of all migrating fishes in some area of water or conveyance where they can be readily sorted into species as desired. It requires sufficient controlled ponded area to be able to accept large quantities of fish in short durational migration surges, which occur in nature, and average these surges over such periods as secondary conveyance requires. It requires, in these facilities, assurance that excessive fish energy is not dissipated and that delays in migration are reduced to a minimum. Economy also requires that those fish extracted from the desired species be put to useful use. The ideal facilities must be satisfactory for processing of all waste.

There is no difficulty in obstructing a stream or river to eliminate the passage of all migrating fish, and this must be done. Our present fish ladders are satisfactory in lifting salmon to some height in their passage over dams but they are also satisfactory in lifting predators and passing these fish over the same dams. This direct connection from tailrace to head pond, while beneficial to salmon migration, is a definite detriment to the production of this specie.

However, to concentrate all fishes for sorting, it is necessary to remove them from the turbulent rivers into areas where they may readily be controlled. Fig. 2 is a diagrammatic sketch showing a plant layout for the extraction of all predation and processing this waste flesh for useful use*. The plant also levels out natural quantity migration surges to capacity of secondary transportation and allows for hatchery propagation when desired.

The process is simple. As the fish are restricted from migrating further up the river channel by a barrier, all species pass up a fish ladder to pool *a*. This lift only needs to be slightly above high water of the river. Screen *b*, of large mesh sufficient to retain only the salmon species desired, is fixed in place. Then as pool *a* is occupied by some fish, screen *c* is placed near the upper end of the fish ladder to stop return of the fish to the river, and it is moved slowly towards *b*. With this progressive reduction of tank volume and allowance for escapement of smaller fish, only salmon and those predators of like or larger size are retained, except perhaps some smaller fish which have not escaped. A small-mesh screen *d* is placed immediately upstream from *b* and the predators in pool *e* are moved to batching hoppers for delivery to conveyor where they may be sorted for market processing or reduced to fish meal or both. In the fish meal we have some fertiliser for rearing areas.

The larger fish between *b* and *c* are then allowed to escape through gate *f* as they are moved along quietly by reducing volume between *b* and *c*. They move into pool *g* over trays *h* separated by vertical screens. These trays with large-mesh bottoms are raised to allow only about 6 in of water on the tray bottom, allowing sorting by inspection and removal of large predators to pool *e*. The trays are then tilted, the side of tray adjacent to pool *i* dropped and those fish that pass to this pool are only the desired salmon. The trays are then lifted clear of the water and the separating screens are lifted to allow screen *j* to clear the tank of all remaining smaller fishes, which have passed through the tray bottoms.

The salmon are then passed to pond *k*, which has large capacity for holding fish and therefore levels out the hourly migration surges of the main fish ladder, and loads to secondary transportation by truck, elevator, inclined or otherwise, or fish ladder. The size of pool *g* is dependent on the type of secondary transportation and its relative capacity to natural migration surges. All operating tanks in the circuit assist in this surge regulation.

The plant also allows for processing in hatchery propagation in part or total. In this operation, pool *k*, or part of it, is a ripening pool to retain the adults until such time as they are ready to spawn. They are then moved, as required, over tray *l*, lifted to allow only shallow water in the tray bottom. Those ready for spawning are taken, stripped of their eggs, fertilised and placed in hatchery trays, where they are

* Patents by Val Gwyther, inventor, are pending on methods and devices illustrated in Figs. 2 and 3.

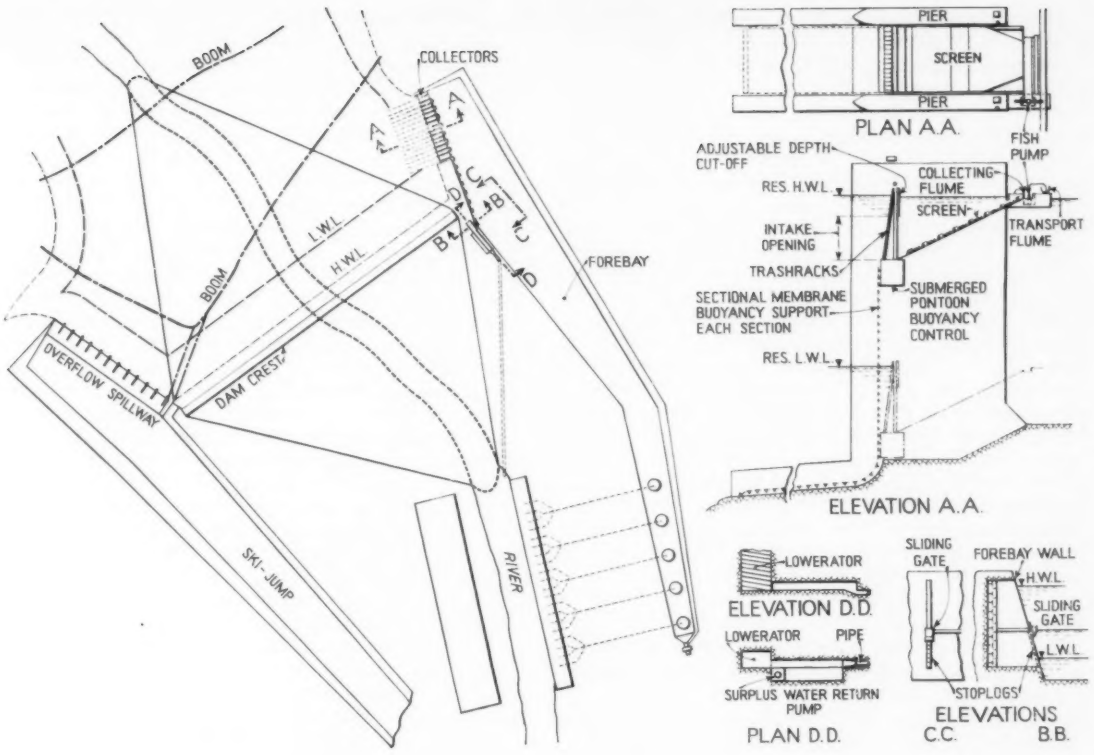

Fig. 3. Downstream migration works for a hypothetical dam

incubated to the free-swimming stage. As this may take from 60 to 90 days, depending on water temperature, pool *k* has no remaining adults. It is then again used for holding these tiny fish by loading to rearing areas.

This plant then allows the extraction of all predatory fishes in their routes of migration and processing this waste fish flesh to useful use. It allows for regulation to secondary transportation, whatever it may be. It allows for hatchery incubation if this is desirable and it definitely allows sorting by size even of salmon, to obtain better stock for breeding or what we generally call selective breeding. Furthermore it allows for extraction of those predators, such as trout, from rearing areas of salmon, as these fish migrate from lakes to incoming streams to spawn.

Downstream Migration

Downstream migration facilities are more difficult than those previously discussed. We must provide for collection of all fish at all stages of reservoir drawdown prior to turbines and also those migrants which may pass in free overflowing spillage. In addition, satisfactory quality water for fish must be made available in the upstream reservoir and downstream river channel at all stages of reservoir drawdown to ensure no pollution of waters during fish migration.

It must be remembered that salmon in such a river as the Fraser start to migrate in early April when reservoir levels are at a minimum, and the migration continues to June, when this river is in flood. In our coastal rivers the fish migrate at about the same time of the year, but are decreasing in flowage as migration proceeds.

In the passage of these migrants we must allow for natural quantity surges as in adult migration. More than six million yearlings migrated from Chilco Lake in seven hours or at an average rate of about one million per hour. The intensity at any particular time may have been much higher, and mixing of other races in the main stem of a large river may also occur. This suggests that all works for the passage of yearlings should have a capacity of many times this quantity. Assuming, then, that this rate of migration may be six million per hour over many continuous hours, and using an index of fish saturation in water of one pound of fish (45 to pound) to one US gallon of water, which is the trucking index, we require about 5·3 cusecs of water to contain these fish satisfactorily. Larger quantities of water in this rate of migration will of course be beneficial.

Fig. 3 shows a general layout of a hypothetical hydro-electric power development which may occur on any river. The dam is shown as a large sectional area for earth- or rockfill, but any type of dam may be used. The free-flow spillway is shown on the left with skijump profile to reduce mortality of downstream migrants to a minimum, and a series of collectors for these migrants are shown on the right. All turbine waters pass through the collectors and thence to the forebay from which it may be accepted by the turbines in many ways. As this water passes through the collectors, carrying with it migrating fish, the fish are abstracted over the end of the screen and thence to

the river below the dam, being carefully husbanded in the entire operation.

To ensure proper-quality water at all times, a curtain wall or membrane is supplied to restrict lower water from passing to the forebay and another curtain wall is supplied to restrict upper lake waters. The opening to the forebay is then in a comparatively shallow entrance conforming with that stratum of water which is satisfactory for fish. The entire collector works between the retaining piers is buoyancy controlled and the sectional parts of the curtain wall are self-supporting, with the exception of a slight residual load. Hoist and hydraulic pins are allowed for emergency. Then only known-quality water is passed through the screens for proper migration downstream. The screens are provided with adjustable cover, mechanical and hydraulic cleaning which may be automatically controlled to provide the necessary differential head for water passage through the screens between screen bay and forebay water levels. The fish are collected in a flume and passed to a fish pump, or other means, which elevates these fish in water to a flume and thence through the forebay wall, from which they are passed to the river channel by fish-ladder lowerater and pipeline or other means.

Watershed Value

We are then able to control and protect from hazard the upstream and downstream migration of the salmon species. We are able to eliminate all predatory fish from the migration routes and we are able to prepare rearing areas for these fish with some fertilisation above what nature annually provides in their zone of habitat. With these known facts we are able to forecast with assurance the value of salmon in a watershed, and therefore with power and other resources, the watershed value for optimum development.

What then is the value of a watershed jointly developed for fish and power? As an example, let us take the Clearwater watershed which is a tributary of the North Thompson River, whose waters pass via the Thompson and Fraser Rivers to the sea.

The Fraser River Board[13] advises that the total annual value of this watershed to hydro-electric power is $33,401,000, of which $3,093,000 is applicable to downstream benefits in power. There are other benefits, such as flood control, navigation, and agriculture, which I do not intend to go into at this time.

The salmon species has not been able to inhabit this extensive rearing area due to physical obstructions in the river channel. However, it appears some steelhead may use at least part of the watershed for propagation. The value of this watershed to the salmon resource in our present thinking is zero, neglect the steelhead, which are predators.

With our present incorrect approach to the potential fish value in the Clearwater we can then discard this watershed as a producer of fish and it can be used as a single-purpose watershed for the development of power only. How false this statement must be!

Races of salmon appear to thrive more abundantly in physical conditions common to their native habitat. As there are at present no salmon in the Clearwater area, it will be necessary to plant this race from other areas where physical conditions are somewhat similar. The major portion of the Clearwater Lake areas lie between 2,000 and 2,700 ft in elevation, while Myrtle Lake lies at an elevation of about 4,000 ft. It will certainly be desirable to plant only one race of fish in the Clearwater area for proper management and some difficulties may be encountered with this race in rearing in the higher elevation of Myrtle Lake. However, it is assumed that one race can be planted in the total 70,000 acres of the lakes in the Clearwater watershed.

This watershed lies in the interior of British Columbia, where the hardness of lake waters is probably higher than in coastal areas. The potential rearing capacity of coastal lakes is 9,000 per acre. This figure on first appearance appears high, but when broken down it shows that each fish is supplied with the production of plankton from 4·8 ft^3 of water for every foot of depth of reservoir it is able to inhabit.

To be very conservative, let us then assume that the fertility of the Clearwater lakes, without feeding, is sufficient to support 3,000 reared yearlings per surface acre. Then with 70,000 acres we will produce a yearly migration to the sea of 210 million small fish. With a mortality of 20% in hatcheries and the predator-free rearing areas, we require 262 million eggs. Also, with 10% survival in the sea life of these fishes, we will obtain a return of 21 million adult salmon each and every year for production and escapement to perpetuate the species.

The female sockeye of the Cultus Lake race varies in egg content of about 4,500 in most years, but only about 3,800 was recorded in 1933[14]. Assuming then, that a female salmon will produce an average of 4,000 eggs at hatchery, the number of adult females required is 65,500. While the sperm from one male is sufficient to fertilise the eggs of many females at hatchery, it does not appear possible, at this remote distance from the sea, to segregate the males at some downstream point and we must therefore allow natural migration, which may be in equal number of males and females. Then with allowances of 25% for losses during migration, it will be necessary to protect in all facilities in the entire migration route from sea to hatchery diversion at least 163,750 adult sockeye salmon.

The net yield to the fishery at the sea is then 20,832,250 adults yearly from the Clearwater or at 7 lb per fish is about 145 million pounds of sockeye salmon fish flesh yearly, which can readily be assessed in primary wholesale value of raw fish flesh.

However, there are some problems in upstream migration. In a watershed such as the Fraser, upstream migration occurs from June to November, but the migration of any race such as the Clearwater will take place in much lesser time. While this migration will be over a month or so, the majority of fish will migrate over a few days and in high surges over a few hours. In the Lower Fraser from Yale to the confluence of the Thompson, and in the Thompson from this point to Kamloops Lake, we may at some time in the future have multiple dams in these two 60-mile reaches of the rivers. Assuming we collect the adult requirements of the Clearwater at Yale and transport by mechanical transport to the upper reservoir on the Lower Fraser and again collect these fish at the lower dam on the Thompson and transport to Kamloops Lake, what is the extent of this transport?

With an adult fish weighing 7 lb and the index of water requirements at 1 US gal per pound of fish, we must transport a load of 65·5 lb for each fish or a yearly load of 5,425 tons in each reach. If this migra-

tion occurs over 15 days, the average load per 24 hours is 362 tons. Trucks will make this return trip, 60 miles, in less than 4 hours or 6 trips per day. We then require four 15-ton water conditioning trailers with motive power in each reach of these rivers. Perhaps for emergencies double this quantity is advisable.

In transport of fry from hatcheries to rearing areas this same transport is satisfactory but capacities are much less. The Clearwater requires planting of incubation from 262 million eggs. Neglecting hatchery loss and assuming the fry weigh 2,000 per lb, we then require transport for about 500 tons per year, which one of these trailers can readily handle.

It must be appreciated that motive transport may not be necessary for fish passage over high dams such as Moran. The fish can be passed to elevators and thence to flume for passage to reservoir. The actual loss in migration time in either of these transportation systems and the dissipation of fish energy can be much less than the time which is now being consumed in natural migration as this rate of passage appears to be from 20 to 30 miles per day, and may not vary, with water velocities encountered.

Economy

The value of raw sockeye fish flesh at boat has greatly increased in price in the past few years. In 1959 this price was 30 cents per lb and in 1960 the price per lb was 33 cents. It is doubtful if large-quantity sales of end product in regular yearly markets can be maintained at this price level. It may, then, be beneficial to the industry to purchase raw fish at a much reduced price, with large quantity production. Assuming then that the price at boat is 15 cents a pound for all sockeye fish developed from the Clearwater area, where none exists at present, the yearly value received by fishermen for raw fish harvested at boat is $21,874,000.

We can, then, conservatively assess the salmon resource value of the Clearwater watershed at a yearly value of about $22 million, which when combined with the related primary wholesale value of hydro-electric power ($30 million), indicates a total watershed value in these two resources of $52 million yearly.

In past experience, in hydro-electric power developments where it has been necessary to maintain the present populations of the salmon species, the cost of power development has been increased to provide facilities for this purpose. These additional costs appear to be in the ratio of from 5 to 10% of power-development cost and have been higher in smaller projects. With proper facilities for production of salmon in quantity it appears that these additional expenditures may not be much greater than past experience, even though such additional work as hatcheries and preparation of rearing areas are necessary. Then with an additional expense of perhaps 10 to 20% we may greatly increase the value of the watershed.

Conclusions

There is no doubt we can now produce the salmon species in great quantities, jointly with other resource values and with economy. We are now able to protect the upstream and downstream migrating fish in their routes of migration. We are able to extract migrating predators in these routes of migration, thereby eliminating these species. We are able to eliminate predation from rearing areas and we are able to control discharge from reservoirs to ensure satisfactory water quality for migration of both upstream and downstream migrants of the salmon species.

The rearing capacity of our natural and impounded lakes is greatly in excess of the yield by incubation from natural spawning grounds. Incubation of eggs must be provided in such quantities as are necessary for the rearing capacity of the lakes and such increases in the rearing capacities as we may wish and are able to make in time to come.

The present policy of retardation of power developments in a watershed, due to our inability to produce the answer to beneficial fish migration, is in the past and these watersheds are now open to development of both fish and power.

As each and every drop of water and flake of snow falls in a watershed and is collected in storage reservoirs for regulation at sites where height of fall is available, we obtain the benefits of hydro-electric power. This same drop of water and flake of snow as it erodes the geological formations of the watershed accepts chemical hardness and transports this hardness to the same storage reservoirs as the food for fishes. Then, in the development of the numerous drops of water and flakes of snow we obtain the associated development of fish and power, or we obtain optimum watershed resource value.

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Harza News. Harza Engineering Company, the Chicago consulting engineers, have sent us a copy of the first issue of *Harza News*, which is intended primarily as a staff magazine. Nevertheless the magazine gives a useful indication of the wide scope of the work undertaken by the company. This issue includes a brief survey of the Indus Basin scheme in West Pakistan, and mentions new river schemes at Guri on the Caroni River, Venezuela, Mahoning River, Ohio, Kingsport, Tennessee, and Yarmouk-Jordan. Notes are also included about the Priest Rapids report and about the Lake Michigan diversion scheme.

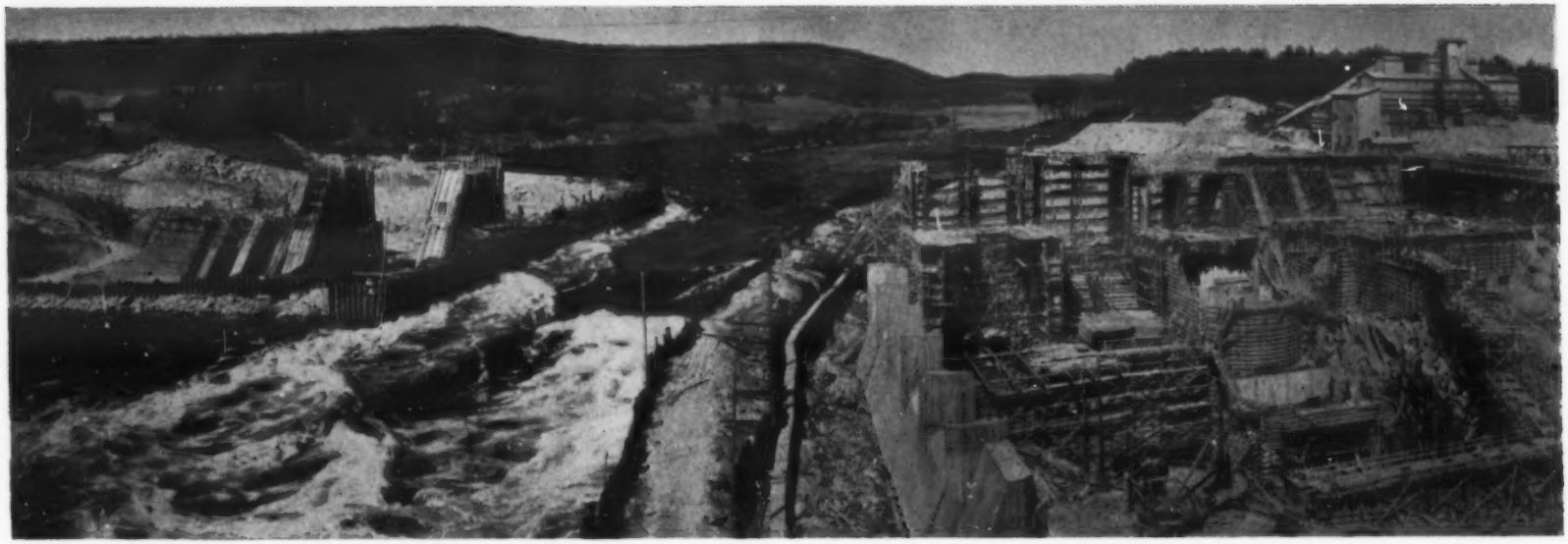


Fig. 10. View of Pengfors station under construction in 1953 during a spring flood of 1,250 m³/sec

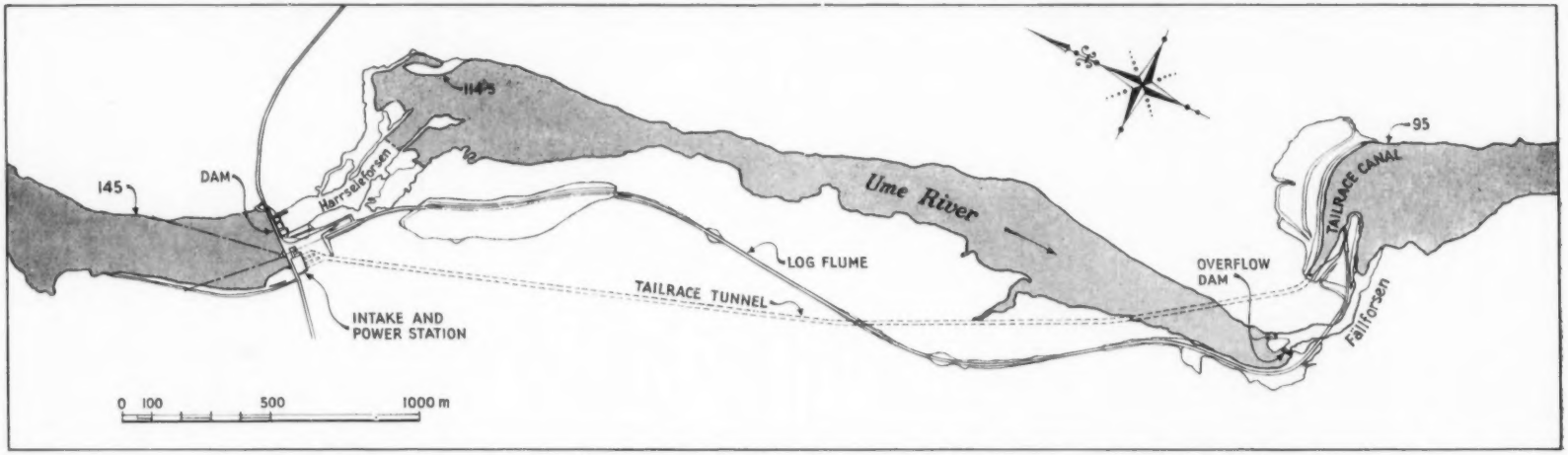


Fig. 11. Map of the Harrsele development, showing the routes of the tailrace tunnel and the log flume

Fig. 12. The control room in Harrsele underground power station

The Development of the Ume River

This article describes the chain of four privately owned stations—Upper and Lower Bjurfors, Harrsele and Pengfors—above the Swedish State Power Board's station at Stornorrfors

PART TWO

IN our first article we presented an overall picture of the development of the Ume River and described the series of stations, mainly owned by the Swedish State Power Board, in the upper half of the main watercourse. We now come to a chain of four privately owned stations lying between the State Power Board's plants at Tuggen and at Stornorrfors. Reading from upstream to downstream they are Upper Bjurfors (11·51 m head, 42 MW, 204 GWh per annum), Lower Bjurfors (20 m head, 72 MW, 362 GWh per annum), Harrsele (54·5 m head, 210 MW, 955 GWh per annum), and Pengfors (15·5 m head, 55 MW, 280 GWh per annum). These production figures are based on a future total storage volume of 3,500 million m^3.

In this article, however, we prefer to describe them in order of construction, which is from downstream to upstream. Pengfors station was commenced in 1951 and completed, with all units in commission, in 1957, Harrsele followed from 1953 to 1958 and Lower Bjurfors from 1956 to 1960. Upper Bjurfors, which was commenced in April 1959, is still under construction and is scheduled for completion in 1962.

Each of these stations is in the hands of a correspondingly named company—Pengfors AB, Harrsele AB and Bjurfors AB—but as the the companies, together with a fourth one, Hjälta AB, are owned by much the same shareholders they have a joint administration, named Norrlandskraft AB, with its head office in Stockholm and a central operation office in Umeå. When the Hjälta station was commenced in 1944 a Construction Department under Mr. Ragnar Ahlström was organised in Stockholm. Since that time this department has been responsible for site investigations, general and construction planning, and management of the civil-engineering works; since 1950 the mechanical and electrical sections have been in the charge of Mr. Nils Helledaij, Chief Engineer. The consulting engineers have been AB Vattenbyggnadsbyrån (VBB), Stockholm. Professor Sven Ivar Lind, Stockholm, has been the architect.

Harrsele and about 80% of Lower Bjurfors were built by the owners under their own management, the Project Manager being Mr. Jörgen Jörgensen. Pengfors was built by AB Skånska Cementgjuteriet; about 20% of Lower Bjurfors and all of Upper Bjurfors by Nya Asfalt AB.

All four power stations have been designed for a maximum nominal discharge of 420 m^3/sec, and in each station are installed three generating sets, of a capacity to suit the head and discharge available. KMW turbines have been chosen for all stations and are of the Kaplan type except for those at Harrsele,

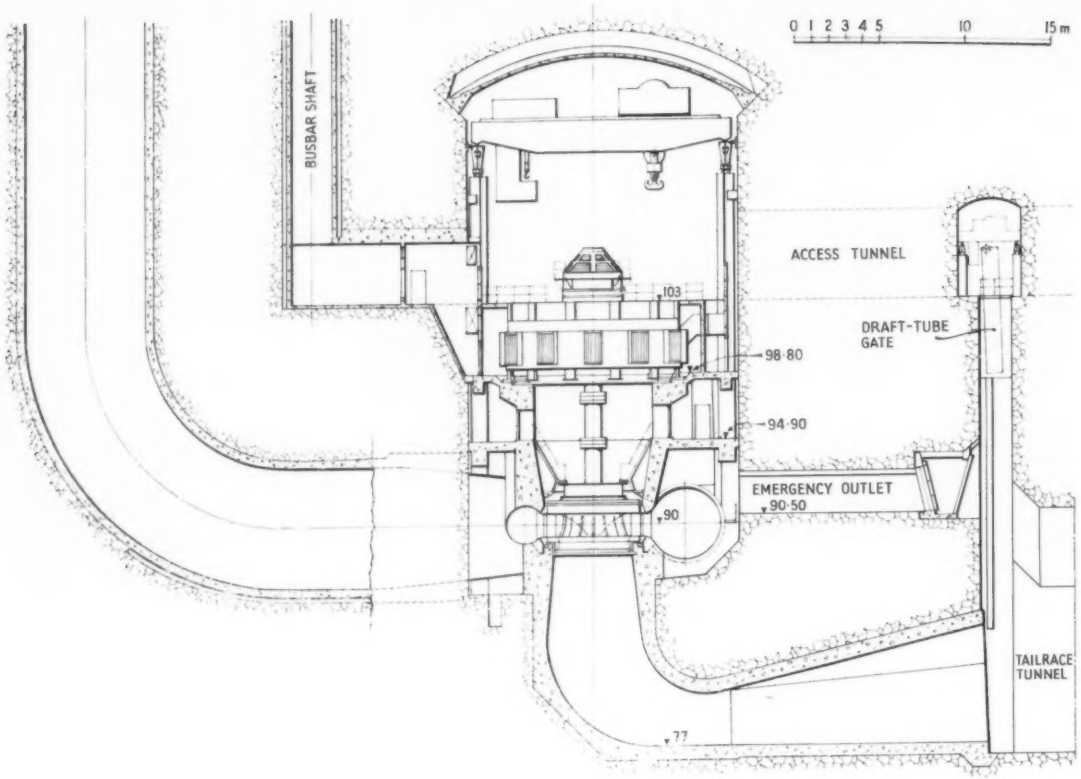


Fig. 13. Transverse cross section through Harrsele underground station

which are Francis machines. ASEA have supplied all the generators and electrical equipment except for the distance protective system for the transmission lines, which is partly of Brown Boveri manufacture.

The spillway for each power station is of the three-opening type; two of the openings, 20 m wide by 7·2 m high, are controlled by tainter gates, and the third, 20 m wide by 6·8 m high, has a downward-opening sector gate. Both tainter gates are fitted with heating devices, and for reasons of safety one tainter gate is operated by direct current, which is available from the station battery. Except for a built-in log-floating arrangement in the sector gate at Upper Bjurfors the gates at all four power stations are identical

Nearly four and a half million logs, on the average, are floated over this section of the Ume River during the season, and a maximum has been reached of over six and a half million logs. Log flumes have accordingly been provided at all stations, the log flume at Harrsele being of more than ordinary interest.

Pengfors Station

Pengfors station is situated on the left bank of the river; immediately to the right of the station is the log flume, and to the right of the log flume is the concrete spillway. On either wing of the station spillway structure the valley is closed by an earth dam.

Three 18-MW generating sets are installed in the station, the water entry to each turbine being controlled by a tainter gate built by AB Hedemora Verkstäder. A short concrete penstock behind each gate leads to a concrete spiral casing. The three turbines discharge to an open stilling basin which is succeeded by a free-flow tunnel 300 m long and 220 m^2 in cross section. The log flume is 440 m long and curves round to discharge into the tailrace canal close to the tunnel outlet.

The simultaneous construction of the spillway and power-station blocks involved a difficult cofferdamming operation, as the distance between the right-bank and left-bank cofferdams, which were of sheet-steel piling, was only 35 m. Nevertheless, as will be seen from Fig. 10, the cofferdam successfully withstood the spring floods.

To comply with the requirements of the War Protection Board the power station was built in reinforced concrete, and the transformers are housed in bomb-proof cubicles. The power-station roof is carried on prestressed and prefabricated concrete beams, each weighing 5 tons. A 4-in layer of concrete was poured on these beams, and this layer formed the base on which the main roof slab was poured. In this manner expensive formwork was saved.

Generation is at 9 kV but the machines are insulated to 10 kV standard. Each generator is connected by four cables to a 23-MVA 9/145-kV $\pm 4\%$ three-phase transformer, the generator neutral point being earthed through a resistance which limits an earth-fault current to 5·5A. From the transformers overhead conductors are taken to a 130-kV switchyard, where the 130-kV air-blast circuit breakers used for paralleling the generating units are situated.

On the 9-kV side two of the generators supply two

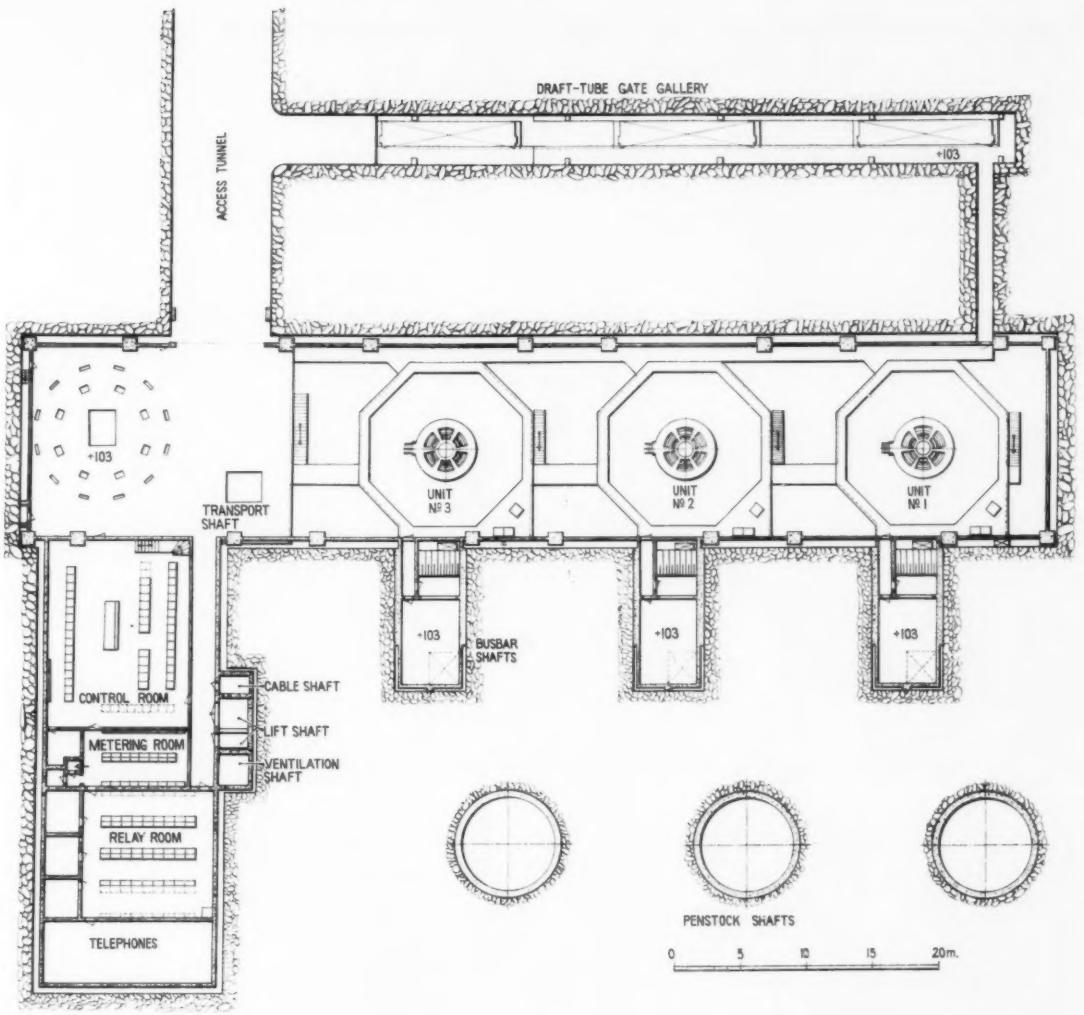


Fig. 14. Plan of Harrsele underground power station

800-kVA auxiliary transformers which are provided with induction-type voltage regulators and furnish a low-voltage supply at 380 V. An emergency supply can also be obtained from Vännas Kraft AB or from the other stations in the group from a 40-kV system through a 1,000-kVA 44/9-kV transformer

Harrsele Station

Except for Stornorrfors, Harrsele station is by far the largest station on the River Ume. It contains three 70-MW Francis machines operating under a gross head of 54·5 m. As will be seen from the general map given in Fig. 11, this head is formed by the combined falls of Harrseleforsen and Fällforsen, which are about 3½ km apart, so that a major feature of the construction is a tailrace tunnel 3,400 m long and 260 m² in cross section. This tunnel was driven in two stages, consisting of a top heading and a lower bench, and full accounts of the methods adopted and of the equipment used have been published in previous issues of this journal.* In the light of these articles it is unnecessary to amplify our account of this tunnel except to say that careful geological investigations were undertaken to determine the location of the tunnel and of the associated underground power station. In point of fact the tunnel line originally proposed, up to 70 m west of that finally selected, was abandoned because a section of decomposed rock was encountered. An especially important section was that where the tunnel crosses underneath the river bed. The river is about 150 m wide at this point, and towards the right bank there is a fissured zone associated with a deep ravine. Some concrete reinforcement was necessary in this part of the tunnel, but no serious trouble was encountered.

Seeing that the full flow of the river will normally pass through the power station and the tailrace tunnel, in default of prevention measures about 4 km of the natural river bed would be laid dry. To

* The driving of the top heading was described in "Tunnel Blasting at Harrsele" by Ragnar Ahlström in WATER POWER, November 1956, p. 407, and the removal of the lower bench was described in "The Harrsele Tailrace Tunnel" by Ragnar Ahlström and Jörgen Jörgensen in WATER POWER, July 1959, p. 267.

Fig. 16. Machine hall of Lower Bjurfors station

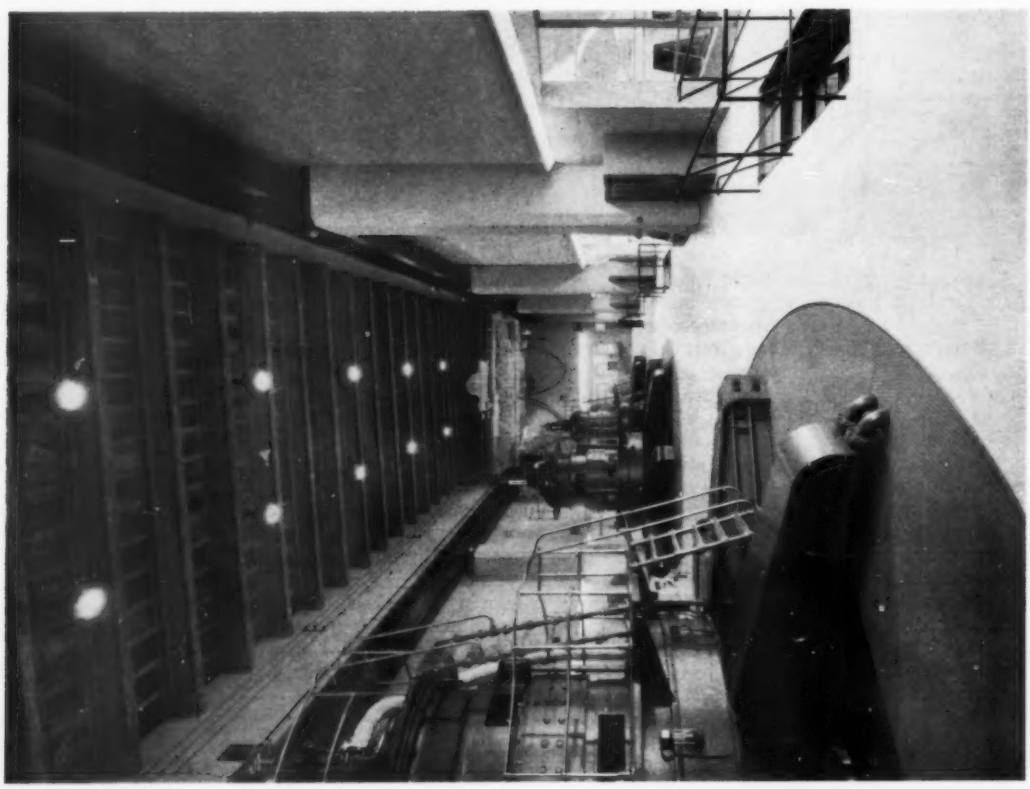


Fig. 15. Machine hall of Pengfors power station

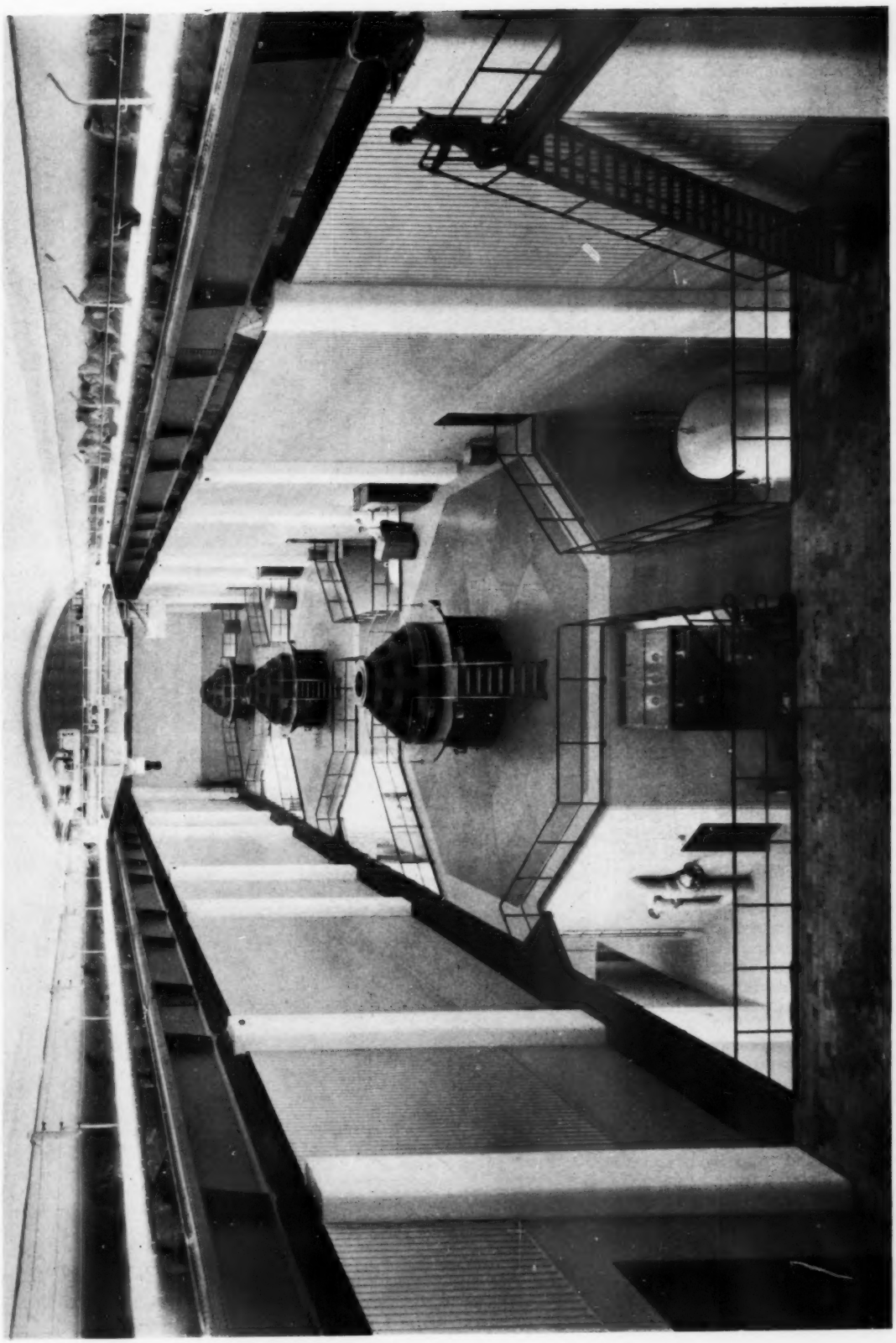


Fig. 17. A view of Harrsele underground machine hall taken from crane level

preserve the scenic attractions of the river a submerged weir has therefore been built at the head of Fällforsen, forming a lake extending up to the foot of Harrseleforsen. Stagnant water is prevented by discharging a small flow of compensation water through a special opening in the spillway section of the dam.

The development of the Ume River for power has entailed consequential changes in the arrangements for log floating, and to compensate for a reduction in the capacity of a log-storage basin downstream of Pengfors a new storage basin has been equipped upstream of Harrsele capable of holding about three million logs.

To pass these logs downstream a log flume 4,170 m long has been built from Harrsele dam to the tailrace canal immediately below Fällforsen. The path of this flume can be seen in Fig. 11, and was determined by the desire to avoid loss of arable land and to ensure that the flume harmonised with the landscape. This has necessitated building the flume with the extremely slight slope of 0·35% over the greater part of its length.

The log-flume intake, built by AB Landsverk, comprises a sector gate to the lip of which is hinged a flared trough offering an intake width of 12 m. For 3,600 m of its length the flume is built of wood staves supported on concrete saddles at 3·5-m centres. Some way below the intake the flume passes over a prestressed concrete bridge, seen in Fig. 18, and discharge openings for excess water are provided in the sides of the flume. At Fällforsen the flume crosses the site of the falls on a suspension bridge. The estimated capacity of the flume is 25,000 logs per hour at a flow of 6 m³/sec.

Harrsele dam is 350 m long, including the power-station intake, and is of concrete except the extreme right wing, which is of earthfill construction. The spillway block—which follows the standard arrangement of three 20-m openings, two controlled by tainter gates and the third by a sector gate—is placed astride the natural river bed. Towards the right bank is the intake for the log flume, and on the extreme right is the intake structure for the underground power station.

There are three intakes, spaced at centre distances of 18 m, each controlled by a tainter gate 15·7 m wide and 10·5 m high, supplied by AB Hedemora Verkstäder. In an emergency these gates can be closed in 30 sec. In front of the gates are bar screens, which can be heated electrically, having clear openings of 70 mm. Each intake leads to a vertical pressure shaft, 7 m in diameter, lined with steel plate ranging in thickness from 10 mm to 24 mm and backed with concrete.

The excavation for the machine hall (Fig. 17) is 80 m long, 16 m wide and 33 m high, and that for

Fig. 18. Harrsele log flume on prestressed-concrete bridge, showing excess-water outlets in action

Fig. 19. Large form panels used in construction of Harrsele dam

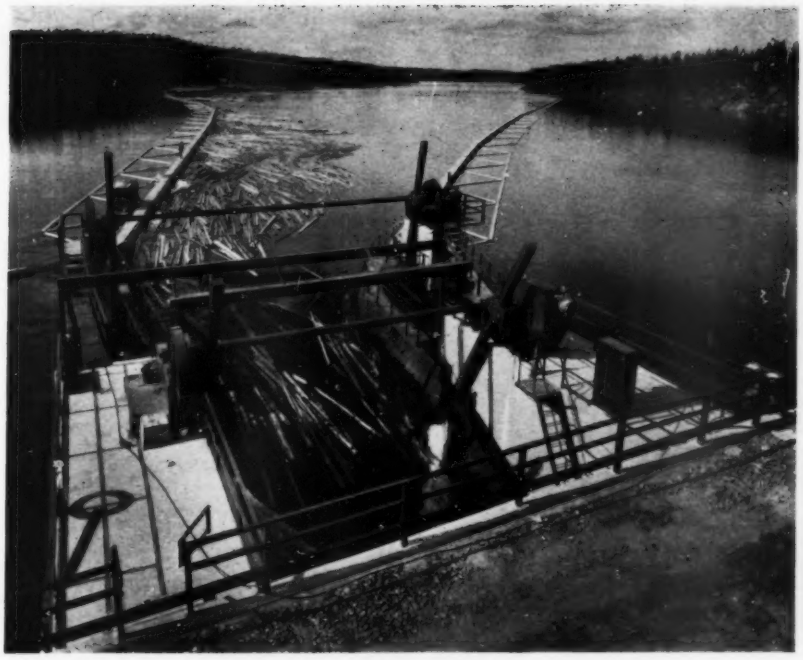


Fig. 20. Intake structure for Harrsele log flume

the control-room annexe, which, as will be seen from Fig. 14, is at right angles to the machine hall, is 34 m long, 14·5 m wide and 15 m high. The station is built in three stories—basement, turbine floor and generator floor; the machine hall floor has been omitted and replaced by steel walkways, as can be seen from Fig. 17. The foundation concrete has been designed to withstand all static and dynamic stresses imposed by the machines and also upward water pressure arising from a burst. To evacuate any such water an emergency outlet passage, normally sealed by a non-return flap, leads from each turbine basement to the corresponding branch of the trifurcation forming the commencement of the tailrace tunnel.

The draft tubes are completely concrete lined, and the vertical and curved parts are also lined with steel plate. Each draft tube can be closed by a stoplog lowered by a crane from a separate gallery. Immediately below the trifurcation a surge gallery has been cut to one side of the tailrace tunnel, having a horizontal area of 3,400 m², and a connection with the tailrace tunnel of 50 m². The tailrace tunnel, already referred to, is succeeded by a tailrace canal, 180 m long, in which abutments have been constructed for a cofferdam of semicircular steel stoplogs if it should be needed.

Excavation of the power station and of the upstream half of the tailrace was conducted through an access tunnel 8·5 m wide, and 5·6 m high, 250 m long, and having a gradient of 1 in 10. The tunnel section was chosen to allow loaded trucks to pass each other at any point, to enable easy passage of trailers loaded with machine parts, and to permit the use of the largest possible loading shovel—a Landsverk L65 machine with a short boom and a 0·9-m³ dipper. Branches were driven from this tunnel to machine-hall roof level, machine-hall generator-floor level, surge gallery, and tailrace tunnel. The surge gallery in turn formed a convenient roadway from which to excavate the draft tubes up to their junction point.

To excavate the machine hall a 53-m² heading was first driven along the roof and stoped out at the sides to full roof width. Concrete arches were immediately set against the roof, and simultaneously the abutments for the inner ceiling were set, but the ceiling itself was left until the hall had been excavated in order to avoid the risk of damage by blasting. When the machine-hall-floor access tunnel had been driven, the machine hall was blasted down to this level in one large bench and mucked out by a 2-m³ shovel. This was followed by excavation of the control-room annexe, a lift shaft and three busbar shafts. In the meantime a heading was carried through the surge gallery, along the roof of draft tube No. 1, through the emergency outlet, along the bottom of the machine hall and into the horizontal parts of the three penstocks. After the vertical parts of the penstocks had been cut, the remaining slab in the machine hall was blasted, the muck being hauled out first from main floor level and later through the emergency outlet.

Most of the drilling was carried out with Atlas Copco BBD 41 WK drills with pneumatic pushers, and the muck was loaded with the Landsverk L65 shovel already mentioned, with Ruston-Bucyrus 19RB and 10RB machines, and in narrow tunnels with an Eimco 104. Large stopes and benches were loaded out with an old Bucyrus-Erie 44B. A fleet of eighteen 14-ton Euclid trucks was used for haulage until they were required for work in the tailrace tunnel, when 5-ton lorries were substituted.

The busbar shafts, lift shaft, and the vertical portions of the penstock shafts were cut by drilling a 200 mm hole down from the surface by means of a well drill to reach the horizontal tunnel. Wagon drills with extension steels then drilled a series of small holes round the main hole according to a firing pattern, and these holes were then charged and fired in sections, commencing at the bottom, forming a central chimney. The shaft was then opened out to full size from the top in the usual way.

Finally an 8·5 m by 5·6 m tunnel was driven from the top heading of the tailrace tunnel to the bottom of the draft tubes, which were driven from the downstream end, and when the machine hall had been completely mucked out connections were opened out to the draft tubes. Great care had to be taken with the rock piers between the draft tubes, and the pier between units 1 and 2, which contained unsatisfactory rock, was completely encased in concrete and anchored with long steel rods.

To reduce construction time, as much of the machine-hall concreting as possible up to generator-floor level was completed before installation of the machinery was commenced, recesses being left to receive embedded parts. Concrete columns for the crane beams were then brought up by means of sliding forms, and it was thus possible to erect one of the travelling cranes at an early stage. A form was built on this crane corresponding to a section, 6·3 m wide, of the inner ceiling, and each section was cast in turn at one end of the machine hall, transported to its final position by the crane, lowered on to its abutments and concreted in place.

The generating sets are KMW/ASEA Francis units operating under a gross head of 54·5 m. Each turbine has a rated output of 90,000 h.p. at a net head of 52·6 m and a discharge of 140 m^3/sec. At 54·0 m net head the maximum output is 93,000 h.p. The guaranteed efficiency was 92·5% and the maximum efficiency measured in the station was 92·9%. The running speed is 125 r.p.m. and the runaway speed 230 r.p.m.

A combined thrust and guide bearing is carried on a bracket immediately above the generator rotor, and a further guide bearing is introduced immediately below the rotor. The exciter and permanent-magnet generator surmount the thrust bearing. The generator is rated at 75,000 kVA at 0·9 p.f. and operates at 16 kV $\pm$ 5%. Voltage regulation is by transductor equipment, which, together with a main and auxiliary impulse exciter for each set, has been installed in a separate room to reduce noise in the machine hall. Each generator is provided with differential protection, and the neutral point is earthed through a resistance limiting the fault current to 12A.

Transformation from 16 kV to 130 kV and 380 kV is effected in an outdoor three-phase bank of four single-phase units, one being a standby. In order to minimime the short-circuit power on the 16-kV side, each generator feeds a separate winding in each single-phase unit. Thus each single-phase unit consists of three legs carrying three primary windings, one from each generator, and secondary windings which are connected in parallel. The secondary windings have graded insulation and are of the autotransformer type, the 130-kV lead being tapped off at the appropriate point. The neutral point on the secondary side is directly earthed.

The transformer bank is rated at 225/450/450 MVA at 16/150/388 kV. It is capable of accepting voltages of 400 kV and 155 kV on the outgoing sides and of withstanding a symmetrical three-phase short-circuit of 12,000 MVA. It is self-cooled up to 50% of rated output, beyond which fan-cooled pump-circulated oil coolers are automatically switched into operation.

The transformer arrangement just described entails paralleling the alternators on the 16-kV side and calls for a special system of isolators. The use of separate transformer windings for each generator, however, has made it possible to adopt 16-kV air-blast circuit breakers, as they have sufficient breaking capacity for the duty. These circuit breakers, which are located on the surface near the transformer bank, connect each generator to a separate set of busbars, and from each set of busbars three two-phase isolators control the corresponding primary windings in the three single-phase transformer units. In the case of the standby unit three complete sets of isolators are provided to enable it to be connected to any phase of the three sets of machine busbars.

The outgoing lines from the 130-kV and 380-kV bushings are taken to separate changeover switchyards each containing six isolators—one for each main unit and three for the standby. From these changeover switchyards the lines go to the corresponding line switchyards, which contain air-blast circuit breakers for the main transformer and for the transmission lines. All isolators concerned with switching-in the standby transformer unit are d.c.-motor operated and remote controlled from the underground control room, and are interlocked.

Two 2,000-kVA station-service transformers, with on-load tap-changers, provide local power at 10 kV, from which a low-voltage supply is derived at 380 V. A 220-V 494-Ah/1-h battery provides power for d.c. motors and emergency lighting, and two 24-V batteries and one 12-V battery are installed for signalling, alarms, telecommunications, and so forth.

The control room, which is at machine-hall-floor level, is depicted in Fig. 12.

The Bjurfors Stations

The Bjurfors rapids offer a head of over 30 m, and the prospects of developing them in a single station were investigated. Comparative studies, however, revealed that two stations would cost little more than the single station, and would offer the advantage of inundating a much smaller area of useful land. It was therefore decided to build two stations, one, Upper Bjurfors, utilising a head of 11·5 m, and the other, Lower Bjurfors, about 7 km downstream, developing the remaining 20 m. As stated at the beginning of this article, Lower Bjurfors is now in operation, and Upper Bjurfors is in course of construction.

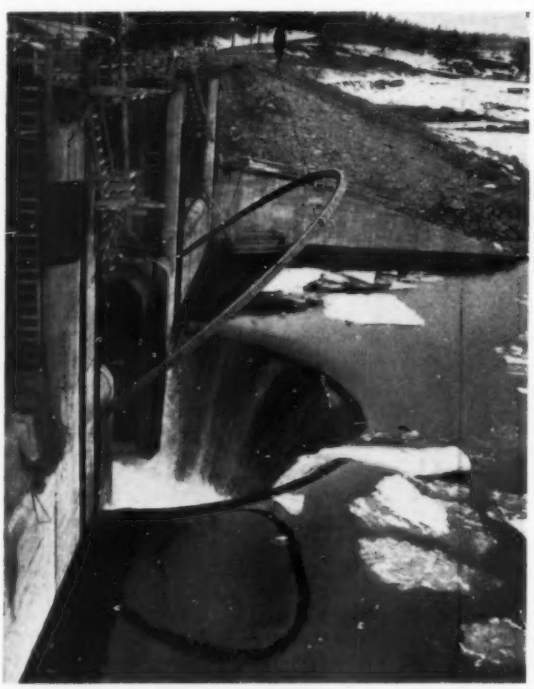


Fig. 21. Lower Bjurfors dam being closed by semi-circular stoplogs

Fig. 22. Upper Bjurfors under construction, August 1960

Lower Bjurfors needs little detailed description as it is almost a replica of Pengfors, both in general site layout and in the design of the station. The main difference is that it has been permitted to use a lighter building construction. The power-station building has a framework of prestressed concrete, and the walls and roof are filled in with lightweight concrete covered with thin corrugated copper plate. A system, first used by this group of companies at Harrsele, of using large panels of ready-made formwork in erecting the building structures was used to an increasing extent. These panels could be used repeatedly and reduced formwork costs considerably.

The general arrangement of the dam is generally similar to that at Pengfors but it is longer and totals 535 m at crest. The left wing is formed by an earth embankment 150 m long, next comes the power-station intake structure, then the log-flume intake, next the spillway structure, and finally an earth dam 215 m long meeting the right bank. The earth dams are constructed with sloping moraine cores. As at Pengfors, the turbines discharge into an open compensating basin which is succeeded by a tailrace tunnel, 550 m long and 260 m² in cross section.

Three 24-MW generating sets are installed. The turbines, of the Kaplan type, run at 125 r.p.m. and each develops 33,000 h.p. under a net head of 19·5 m and a discharge of 140 m³/sec. The alternators generate at 11 kV.

A departure from the Pengfors layout is that the main transformers stand on a concrete platform over the draft tubes and immediately outside the downstream wall of the machine hall. Each generator feeds its own three-phase transformer, and the busbar connections are only about 16 m long. Each transformer is rated at 28 MVA and steps up to 154 kV $\pm$5%.

The high-voltage circuit breakers are of the minimum-oil type and have a rupturing capacity of 2,750 MVA at 140 kV.

The local 10-kV network is supplied from the generator busbars and the 380-V station supply is provided by two 800-kVA transformers with induction regulators.

At Upper Bjurfors the river is closed by a comparatively short concrete gravity dam built straight on the rock. To the left is the spillway, which is of the normal three-opening type but has the unusual feature that the log flume is combined with the sector gate. This flume is very short and discharges over the tailrace at the foot of the power station.

The power station is immediately to the right of the spillway and contains three 14-MW Kaplan sets operating under a head of 11·5 m. Tainter gates are not used to close the turbine inlets, but control is effected by a single vertical roller sluice gate which can be lowered by a crane in front of any of the three openings. This arrangement is much less expensive than tainter gates, and is considered to be adequate because the output of one of these machines is small in comparison with the total capacity—380 MW—of this chain of four stations. The somewhat longer outage time occasioned by this arrangement is not, therefore, of much significance. The manoeuvring of this roller suice gate will be carried out automatically.

Lightweight construction is again being employed for the power-house building, and in this case further lightening of the structure has been achieved by using a semi-portal-type machine-hall crane.

The three generators, which will operate at 10 kV, will be paralleled on the 10-kV side and will be connected to a single 50-MVA 11/154-kV three-phase transformer. Both Bjurfors stations will be remote controlled from Harrsele by carrier current over the 130-kV lines.

Acknowledgments

In publishing our description of this group of private plants on the Ume River we should like to express our indebtedness to the headquarters administration of the three companies concerned for their permission to visit the stations and for the information, drawings and photographs so freely placed at our disposal. We particularly appreciated the kindness of Mr. Ragnar Ahlström, the Chief Engineer, who travelled specially from Stockholm in order to conduct us personally round the various works. Our account of these stations—gravely inadequate as it is, on account of pressure on our space—owes much to his ready help.

(To be continued)

Ninth IAHR Congress

The Ninth Congress of the International Association for Hydraulic Research was held in Dubrovnik, Jugoslavia, in September. We publish some notes on those papers dealing with the use of computers and analogues in solving hydraulic problems

PART ONE

AT the Ninth International Association for Hydraulic Research Congress in Dubrovnik, nearly 300 engineers from all parts of the world reviewed some 130 papers at four sessions and three informal seminars, including one on hydraulic machinery. The subjects and origins of these papers are analysed in the accompanying table.

A departure from normal procedure was the introduction of three lectures by authorities on special topics, namely: "Hydraulic Problems of the Karst," Prof. Bogic Knezevic (Belgrade University); "Three-Dimensional Flow Across the Boundary Layer," Prof. H. Schlichting (Institute of Fluid Mechanics, Braunschweig); and "Energy Transformation in Separation Zones," Dr. Hunter Rouse (Iowa Institute of Hydraulic Research).

There were many papers of theoretical and practical importance, frequently supported by model tests, dealing with research on the selected themes as listed at the end of these notes. They are of interest not only for their technical content but also because they reveal problems that are important in the USSR and Eastern Europe. A correlated analysis is impracticable, but two methods became evident from them and the discussions as aids to predicting model and prototype performance where computations associated with complex problems are impossible or uneconomic by manual methods. These tools, commonly used in other engineering fields, relate to electronic computers and electrical analogues. While a session was devoted to the broad applications of the former, the latter were dominant in Section II on "The Mechanics of Ground Water Flow." These notes are confined to the papers which demonstrated their application and interrelation.

GENERAL PAPERS ON COMPUTERS

III/2. Electronic Computers and Similar Devices. Advani (India)

This paper outlined the value of network models, electronic digital and analogue computers for problems where accurate manual iterative calculations become time consuming, such as:—

(i) River-flow forecasting from hydrological, meteorological and other statistical data.
(ii) Sediment load transport.
(iii) Reservoir operation.
(iv) Water-surface profiles.
(v) Hydraulic transients.
(vi) Ground-water flow.
(vii) Complex pipe networks.

which were elaborated in other communications.

III/12. Computer Language. Bugliarello (USA)

The philosophy and development of a synthetic computer language for hydraulic problems is examined in this paper, which claims that it could lead to improved techniques and automation of routine tasks. A survey of the principal computer operations, mainly from the hydrological and cognate fields, indicates that a minimum of 300 operations would suffice for the traditional approaches, to which statistical

Theme	Technical sessions				Seminars	
	I	II	III	IV	A	B
Countries / Subject	Turbulence effects	Ground-water flow	Computer application	Stream modifications	Irrigation and drainage structures	Free-surface and unsteady flow
Western Europe	2	9	31	6	1	12
Eastern Europe	15	21	2	15	4	20
Middle and Far East	4	4	3	3	2	2
North and South America	6	1	6	2	2	3
Africa and Australasia	—	1	—	1	1	1
Totals	27	36	42	27	10	38

processes such as queuing and random walk methods, linear and non-linear programming, economic and cost optimisation considerations should be added. It is admitted, however, that this may demand large memory features or splitting the programme into separate phases. Processing involves arithmetic, secondary and buffer storage, into which universal, hydraulic and machine language appropriate to the problem are fed as subroutines from series or parallel data sources.

It is concluded that feasibility warrants investigation.

HYDROLOGY

III/6. Hydrological Applications. Normand (France)

Hydrological calculations involving a limited number of phenomena using hourly or daily flows, levels or other extensive statistics are suitable for tape recording and feeding into and conversion by an electronic computer programme. Apart from conventional statistical operations like data classification, means and standard deviation, third- or fourth-order moments for Pearson distributions, and significance and confidence limits which can be promptly modified as survey measurements become available, theoretical research should also widen the scope of computers especially when natural conditions can be expressed mathematically via multiple correlation which can be investigated cheaply. Unit hydrograph development from rainfall data is being attempted.

III/16. Run-off Analysis. Isihara (Japan)

The concept here is that flood run-off from heavy storm or typhoon rainfall consists of non-uniform sheet ground surface and subsurface flow through porous media on a complex catchment, expressed as a non-linear partial differential equation of two-dimensional diffusion with convection and distributed and forced inflow. An electronic analogue computer comprising lumped series resistance and shunt capacitance circuits and a non-linear electromotive force was devised for evaluation of a simplified fundamental equation. Its application is illustrated by the Yura-River-catchment hydrographs for two successive rainfalls of the same intensity and total duration occurring in different order; the results appear to agree with experience.

III/18. Run-off from Rainfall Data. Van den Berg (Holland).

Correlation between rainfall and the River-Niger discharge was established and the total catchment run-off calculated with an IBM 650 electronic computer from 20,000 observations. Coefficients were evaluated for the 165 rain gauges by the Thiessen method and the network reliability confirmed quickly and cheaply.

Relative costs for computer and manual calculations are given.

III/13. Discharge Record Transformation. Nash (Great Britain)

Because of channel obstruction clearance it was anticipated that the catchment rainfall response would change. Existing records and correlation with neighbouring catchments allowed the "pre-works" and "post-works" hydrographs to be related via matrix representations adapted to a high-speed computer.

III/25. High-River-Discharge Water Levels. Wijngaarden and Sijbesma (Holland)

Extreme-flood-level investigations along the Dutch Rhine and its branches in terms of discharge frequency curves resulted in a method of calculation, including friction from dykes and other topographical features, where an electronic computer could be used. For a 5–7-km reach an iterative solution of 60 equations is required.

III/36. Water Utilisation. Pasquali and Rossi (Italy)

The application of IBM 650 and other electronic computers to problems concerning alternative hydroelectric developments based on long-term measurements are reviewed, including:—

(i) Reservoir-discharge distribution using Conti's geometrical analysis.
(ii) Power-plant generation.

The calculating programmes were applied to the Piave-Boite-Mae-Pontessi system.

III/41. Flood Levels in Shallow Interconnected Basins. Sorensen and Larsen (Denmark)

Storm-flood levels in seven wide and shallow basins, open to the North Sea and Kattegat and interconnected by relatively deep and narrow channels, is treated as a case of non- or quasi-stationary flow with inertia and wind set-up based on momentum and continuity differential equations. The Dask digital computer calculations were confirmed by observed wind speed, high-water levels and frequency statistics.

III/27. Boundary Conditions in a Mobile Bed River Model. Sijbesma and de Vries (Holland)

A tilted model of a bifurcation with a gate in one branch to investigate changes in discharge distribution, solid-material transport and bed levels for varying Lower Rhine and boundary conditions required many complex computations based on actual observations. The model results, checked by backwater-curve iteration procedure on an electronic computer, forecast the changes.

III/28. Grain Sorting in Rivers and River Models. De Vries (Holland)

Measurements in rivers and river models show that phase lags occur between the variations of water depth, velocity, and bed wash-load grain size in bends. The scattered phase lags deduced indirectly from measurements, statistical analysis and correlation, using a Stantec Zebra electronic computer, showed that with steeply graded river beds, "hysteresis" introduced complex transport phenomena which were important in channel-improvement proposals and that model/prototype scale effects demanded further analysis.

III/17. Tractive Forces for Cohesive Soils. Thomas and Enger (USA)

Design criteria for lined and unlined earth channels were programmed on an IBM 650 electronic digital computer via multi-linear empirical correlation of critical tractive forces, a primary agent in erosion, and standard soil properties. The tractive force apparatus produced 8-in hand-cut undisturbed cohesive soil samples from irrigation canals widely distributed geographically, climatically and hydraulically. The samples did not reveal wide deviations in mean

particle size or large quantities of sand or gravel, but fell in a limited range on the plasticity-index/liquid-limit chart. While zoned samples showed higher correlation coefficients, the combined data (within specific ranges of plasticity index, liquid limits, in-situ density and soil gradation) gave a satisfactory general empirical equation. The investigation is being extended to curvilinear relationships.

III/33. Movement of Material in Turbulent Flow. Zaoui (France)

This paper examines sand-trap operation theory involving mixing lengths, concentration, fall and turbulent-velocity fluctuations with numerical parameters conditioning particle suspension and deposition. The differential equations, expressed in finite differences for the electronic computer, were adapted to accommodate advances in theoretical research on suspended materials in turbulent flow. Dimensionless curves relating concentration and efficiency to water depth and distance along the sand trap are given to assist effective and economic dimensioning.

GROUND-WATER FLOW

III/10. Underground Water Flow. Zaoui (France)

If the ground-water and boundary conditions are known, water-table investigations can be reduced to integration problems where electronic computers can be utilised. Details are given of the methods used on an IBM 650 programmed for typical cases including:—

(i) Numerical calculations for complex conditions where the analytical equation is known.
(ii) Wave propagation in porous media using finite differences and the superposition principle.
(iii) Interpretation of observed data on extended nappes.

II/5. Flow in Porous Media Under Protected Foundations. Preissman, Brepson and Clement (France)

Upstream and downstream sealing or leakage-restricting aprons and curtains for barrages on permeable foundations are analysed by conformal representation and reduced to finite difference numerical procedures and compared with the relaxation method in terms of number and length of iterations, cost and accuracy. Since each characteristic point is defined by five parameters, rapid integration on an IBM 650 electronic computer is economical. The programme can be adapted to the domains upstream, beneath and downstream of the barrage with interzone transitions expressed by linear equations. Typical computations agree with theory and electrical analogy methods; formulae are derived for leakage and head loss at a point below the apron. For complex cases involving imperfectly sealed sheet piling or permeability variations the relaxation method is more flexible.

II/1. Uplift Pressure on Structures on Stratified Permeable Foundations. Luthra and Joglekar (India)

A horizontal-floor electrical-analogue model, with variable permeability strata simulated by the electrolyte depth, provided an economical and rational approach to uplift pressure distribution below barrages and dams and the influence of stratification on seepage lines where:—

(i) There are several layers of different permeability.
(ii) An impervious stratum exists beneath a pervious subsoil, or is of irregular shape and distribution.

The summarised results include typical equipotential and flow nets and a case of impermeable pockets at odd positions for which critical-point uplift pressures are compared with those beneath a barrrage without stratification.

II/11. Ground-Water Elevation by Hydraulic Structures. Aravin (USSR)

Changes in the natural ground-water regime caused by operating reservoirs may influence wide areas and the form and dimensions of dam abutments, grout curtains and drainage systems for preventing bank failure. The variable-permeability strata may be superimposed on complex impermeable bedrock and may incorporate river and lake systems. Electrical-analogy methods embracing the percolation region boundary conditions determined equipotential and depth lines by successive approximation.

The liquid electrolyte model is a tank of dielectric (i.e. paraffin) with a curvilinear floor and a.c. electrodes located at the points corresponding to natural bank slopes. Impermeable obstacles are simulated by dielectric plates. In the electro-conductive paper model the electrodes are copper wires with impermeable objects simulated by narrow openings in the paper. For unsteady percolation a continuous-reading hydraulic integrator consisting of a system of vessels interconnected by hydraulic resistors is used.

The procedure is used on large power projects in the USSR including one where a semipermeable layer was confined between upper and lower pervious strata.

II/34. Ground-Water Simulation in Extensive Areas. Halek (Czechoslovakia)

An electrical analogue was chosen for model experiments representing the processes observed in nature in the past and to ascertain future changes in boundary and ground-water conditions caused by hydraulic structures. A resistance/capacitance network, an electrical integrator with voltage dividers, amplifier and generator for producing a voltage of required form, was constructed to forecast the effect of a project on underground water levels. Typical oscillograms show the amplitude of non-stationary condition oscillations, the rapidity of damping and the effect of protective works.

II/2. Standpipe Field-Permeability Tests. Bullen (New Zealand)

In these tests for in-situ permeability near the ground surface, needed during earth-dam construction, flow into the soil is measured through the bottom of a short, shallow cased well of thin-walled open-ended tubing partially embedded and sealed to specific requirements. Boundary-condition analysis and a three-dimensional electrical analogue investigation for pervious and impervious strata was used to assess field-flow measurements at constant or on falling water levels. In this model, the construction of which is described, the permeable soil (assumed homogeneous and unsaturated) is simulated by a conducting medium and water flow by an electric current. The sealed and unsealed permeability coefficients, expressed in dimensionless terms of standpipe radius and head, are applicable to field tests.

Capillarity effects, minimum standpipe size, depth, embedment and test duration in relation to soil-particle size are mentioned.

II/9. Diffusion Phenomena and Seepage Flow. Shima (Japan)

This paper concerns regions affected by tidal rivers or land below sea level and relates to theory and experiments on seepage-flow diffusion with respect to salinity in porous media. A constant-head cylindrical column with electrodes in a sand bed and an oscillograph is used to record salt concentration. Probability calculations confirm analogous heat diffusion and conduction equations with which the experimental results are compared in terms of distance and time of attaining 50% concentration and the relation between seepage head and rate, diffusivity coefficients and sand size.

II/33. Wells with Radial Drains. Kordas (Jugoslavia)

An electro-hydrodynamical analogy is applied to limited-depth wells with radial drains and an analytical expression derived from the results for estimating total yield. The principles of this variable frequency (1,000 c.p.s.) model with electronic voltmeter (5–15 V) and oscilloscope are described.

II/28. Water Movement in Fissured Rocks. Ollos (Hungary)

A model test procedure relating to water movement in fissured rocks, where longitudinal and local head losses, directional changes and significant inertia forces are involved, is described. Physically, the model must reproduce homogeneous or non-homogeneous conditions and the geometric characteristics of the fissured system. An analogy seen between this and a pipe system is the basis of an idealised two-dimensional model formed of a reservoir coupled to small-diameter transparent pipes representing fissure dimensions with piezometers and water-withdrawal tappings at the upper and lower perimeters within the system. The model only furnishes qualitative and visual information about the fissured-system characteristics, faults and caves; pressure-distribution diagrams for combinations of feeding and bleeding points are, however, apparently confirmed by the electrical analogy.

It is proposed to construct a three-dimensional model.

II/26. Excess Water Pressure Under Asphalt Facings of Sand-Cored Dykes. Van Heemskerck (Netherlands)

The excess pressures beneath asphalt facings of dykes exposed to recurring and extreme tidal and storm conditions were determined by a 200–5,000 c.p.s. a.c. analogue. The controlling prototype factors included the influence of:—

(i) Permeability and non-homogeneity.
(ii) Drainage at the dyke toes.
(iii) Trapped air between the facing and the ground water surface.

The analogy is between flow through porous media and electric currents in resistance/capacitance networks. The plate-shaped electrical conductors conform to the water-bearing soil mass and the capacitances simulate water-retaining capacity and permeability variations. Boundary-condition apparatus superimposes tidal and wind effects.

II/14. Non-Stationary Flow Through Embankments. Bernell (Sweden)

Laboratory tests on uniform and non-uniform grain fractions, between the limits of 0·004–0·04 cm, and natural soils including compaction and porosity revealed a critical Reynolds-number transition region where the flow velocity increases exponentially with the hydraulic gradient. This is examined analytically in respect of turbulence effects. Ground-water flows through and levels in embankments where the head is time-dependent, such as impounding or rapid drawdown, are non-stationary and were determined by electrical-analogy equipment. Typical results, illustrated by flow nets with a drawdown-rate parameter, show that over-rapid filling of reservoirs with earth and rockfill dams having moraine cores of different slopes can induce fill settlement, erosion and instability. A practical criterion is given.

(To be continued)

Riva Centenary

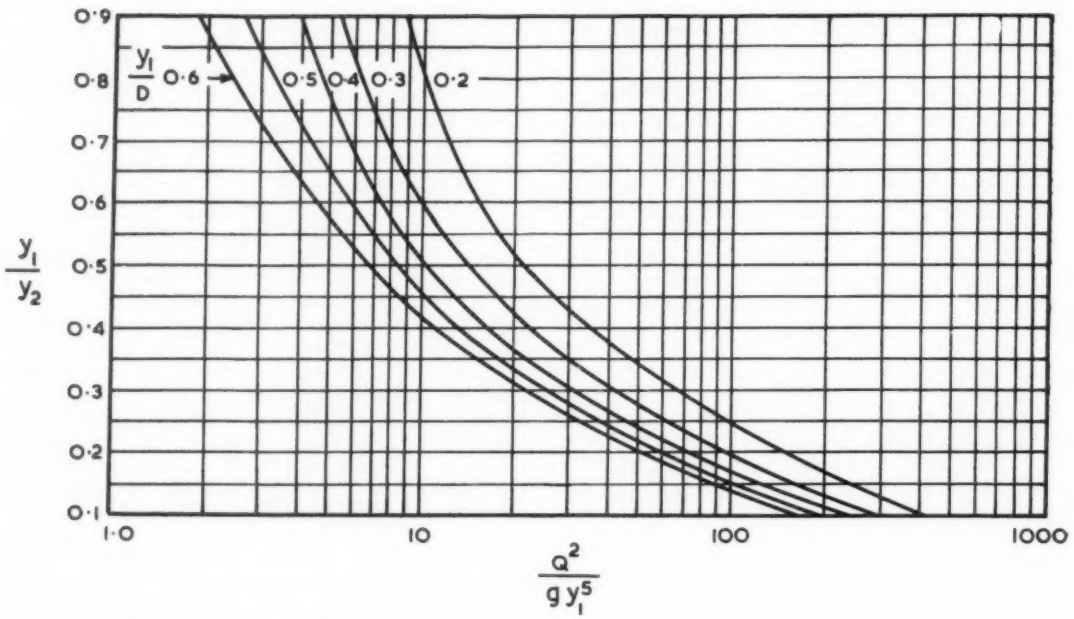
S. A. Costruzioni Meccaniche Riva, Milan, have celebrated their centenary by publishing a magnificent volume entitled "La 'Riva' in Cento Anni di Lavoro," by Guido Ucelli, describing the origins, development and activities of the company. After a brief introduction outlining the development of hydraulic machines in Italy, in which the immortal Leonardo da Vinci played so vital a part, the author traces the history of the firm from its founding in 1861 by Paolotti Antonio and Alessandro Steier. Ing. Alberto Riva, who established an engineering business in 1872, became associated in 1884. The early history is too complicated to detail here, but the company was reconstituted under its present name in 1914. Separate chapters in the book are devoted to Pelton, Francis, and Kaplan turbines, regulators, pumps, research laboratory, and machine tools, and space is also devoted to the work of Riva's associated companies S.p.A. Alessandro Calzoni, who specialise in hydraulic gates, S.p.A. Moncalvi, who build earth-moving and dredging machinery, and the foundries of S.p.A. Caster. Amongst many interesting data there is a complete list of all water turbines built by the company since 1885—totalling no less than 4,544—and a list of pumps, totalling 4,537, built since 1898. The book, which runs to nearly 300 pages, is beautifully bound and printed, on heavy art paper, and is profusely illustrated, many of the illustrations being in colour.

G.E.C. (Engineering) Limited. A new company, G.E.C. (Engineering) Limited, has been formed to take over and develop the engineering activities of The General Electric Co. Ltd. This is in accordance with the new policy of the G.E.C. to form its manufacturing groups into subsidiary companies. The manufacturing resources of the new company comprise the electrical engineering works at Witton, Birmingham, and the mechanical engineering works at Erith, Kent. The total number of employees exceeds 15,000. The Board of Directors of the new company will operate from headquarters in London, negotiations for the acquisition of suitable premises for which are at present in progress.

Hydraulic Jump in Circular Channels

An exact solution of this problem is presented as a sequel to recent articles on hydraulic jump in trapezoidal channels

By A. THIRUVENGADAM*



IN the June 1961 issue of WATER POWER, Massey presented an exact solution to the problem of hydraulic jump in trapezoidal channels, which proved to be simpler in application than Diskin's earlier approximate method (WATER POWER, January 1961). A solution of the case of circular channels, and a simple graphical representation, are also possible, and are given below in order to extend the clarification of this subject.

The notation employed is as follows:

Q = discharge
g = acceleration due to gravity
A = cross-sectional area of flow
h = depth of centre of gravity below the water surface
y = depth of flow at the centre of the channel
D = diameter of the circular channel.

Subscripts 1 and 2 refer to the values upstream and downstream of the jump respectively.

The general form of the momentum equation is:

$$h_2 A_2 - h_1 A_1 = \frac{Q^2}{g}(1/A_1 - 1/A_2) \quad \ldots (1)$$

from which

$$\frac{\frac{h_2 A_2}{h_1 A_1} - 1}{1 - \frac{A_1}{A_2}} = \frac{Q^2}{g h_1 A_1^2} \quad \ldots (2)$$

For a circular channel:—

$$h = \left[8y^3\left(\frac{D}{y} - 1\right)^{3/2} - 12\,Ay\left(\frac{D}{2y} - 1\right)\right]\frac{1}{12A} \quad \ldots (3)$$

and

$$A = \frac{D^2}{4}\cos^{-1}\left(1 - \frac{2y}{D}\right) - \frac{D^2}{2}\left(1 - \frac{2y}{D}\right)\sqrt{\frac{y}{D} - \frac{y^2}{D^2}} \quad \ldots (4)$$

Substituting equations (3) and (4) in equation (2). with appropriate subscripts, and rearranging, we have:

$$\frac{\varnothing_1 \varnothing_2 \frac{y_1^2}{y_2^2}\left[\frac{y_2^3}{y_1^3}\frac{\theta_2}{\varnothing_2} - 1\right]}{1 - \frac{\varnothing_1}{\theta_1}} = \frac{Q^2}{g\,y_1^5} \quad \ldots (5)$$

where

$$\varnothing_1 = \frac{1}{4}\cos^{-1}\left(1 - \frac{2y_1}{D}\right) - \tfrac{1}{2}\left(1 - \frac{2y_1}{D}\right)\sqrt{\frac{y_1}{D} - \frac{y_1^2}{D^2}} \quad \ldots (6)$$

$$\varnothing_2 = \frac{2}{3}\left(\frac{D}{y_1} - 1\right)^{3/2} - \frac{D^2}{y_1^2}\varnothing_1\left(\frac{D}{2y_1} - 1\right) \quad \ldots (7)$$

$$\theta_1 = \tfrac{1}{4}\cos^{-1}\left(1 - \frac{2y_1}{D}\frac{y_2}{y_1}\right) - \tfrac{1}{2}\left(1 - \frac{2y_1}{D}\frac{y_2}{y_1}\right)\sqrt{\frac{y_1}{D}\frac{y_2}{y_1} - \frac{y_1^2}{D^2}\frac{y_2^2}{y_1^2}} \quad \ldots (8)$$

and

$$\theta_2 = \frac{2}{3}\left(\frac{D}{y_1}\frac{y_1}{y_2} - 1\right)^{3/2} - \frac{D^2}{y_1^2}\frac{y_1^2}{y_2^2}\theta_1\left(\frac{D}{2y_1}\frac{y_1}{y_2} - 1\right) \quad \ldots (9)$$

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Equation (5) has been solved for various values of y_1/D and the solution is given in the accompanying figure, from which $\frac{y_1}{y_2}$ can be obtained directly following evaluation of the right-hand side of the equation. Similar solutions can also be obtained for other geometrical shapes by this method if h and A can be expressed as mathematical functions.

Ice Plant for Bhumiphol Dam

In our September 1960 issue we published an account of the Yanhee multipurpose project in Thailand, which will ultimately have a capacity of 560 MW. An important feature of this scheme is Bhumiphol dam, now under construction, which will be a concrete arch structure 154 m high, 52·2 m thick at base, 6 m thick at crest, and 467 m long at roadway level. The building of such a dam necessitated cooling the concrete, and in addition to embedding cooling coils in the concrete lifts it was decided to use crushed ice in the preparation of the mix.

The apparatus for supplying both the chilled water to the cooling coils and the crushed ice to the batching plant was made by Grasso's Koninklijke Machinefabrieken N.V., 's-Hertogenbosch, Holland. Particu-

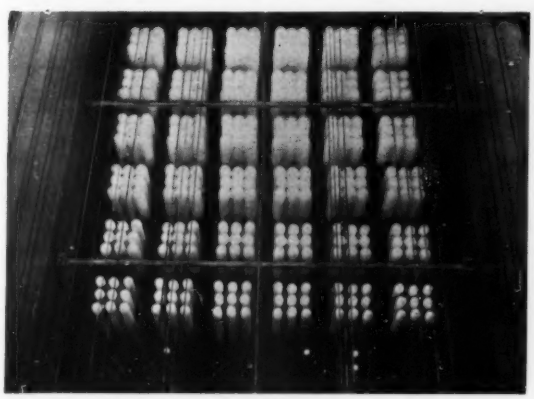


Fig. 1. Ice blocks forming in the freezing chamber

Fig. 2. View of a Grasso ice machine

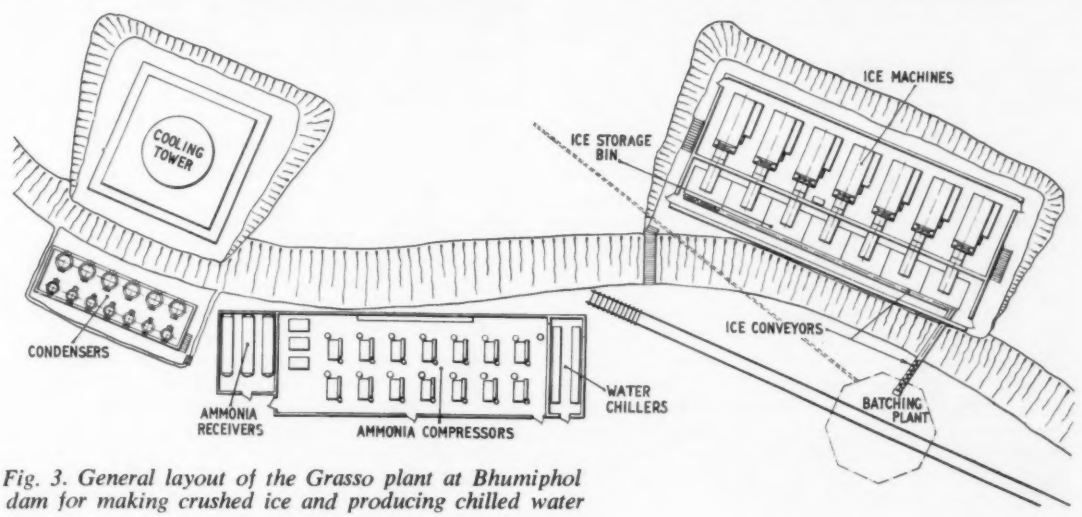


Fig. 3. General layout of the Grasso plant at Bhumiphol dam for making crushed ice and producing chilled water

lar interest attaches to the ice-making plant, which is claimed to produce ice about 30% cheaper than that made by a conventional plant and to require only 25–40% of the space. The plant operates in a continuous cycle and is completely automatic; it produces dry, crushed ice, which, it is said, can be stored for several weeks without deterioration. Seven ice machines have been installed, each rated to produce 30 tons of crushed ice per day; this allows for a total production of 180 tons per day with one machine spare.

Each ice machine consists of a tank in which are placed a series of freezing elements, each comprising a nest of nine vertical freezing cores. Each core is made up of an inner and an outer tube, the outer tube being closed at the top, and the evaporation of liquid ammonia between the inner and the outer tube causes the surrounding water to freeze. A tube of ice thus forms round the core, which at Bhumiphol is allowed to grow to about 5 mm thick, the process taking about 27 min. Incidentally, if solid ice blocks were required they could be produced very simply by extending the freezing period to 3 hours, in which time the ice tubes in each nest would grow together. At the end of the freezing cycle (27 min in this case) hot ammonia gas, tapped off from the compressor delivery, is passed through the freezing cores; this melts the skin of ice in immediate contact with the cores and allows the ice tubes to float to the surface, whence they are skimmed off by a rake-type conveyor. In each machine there are nine rows of freezing elements, so that a batch of ice tubes is delivered every three minutes, the entire operation being automatically controlled. Fig. 1 is a view looking into a standard ice machine and showing the gradual formation of ice blocks.

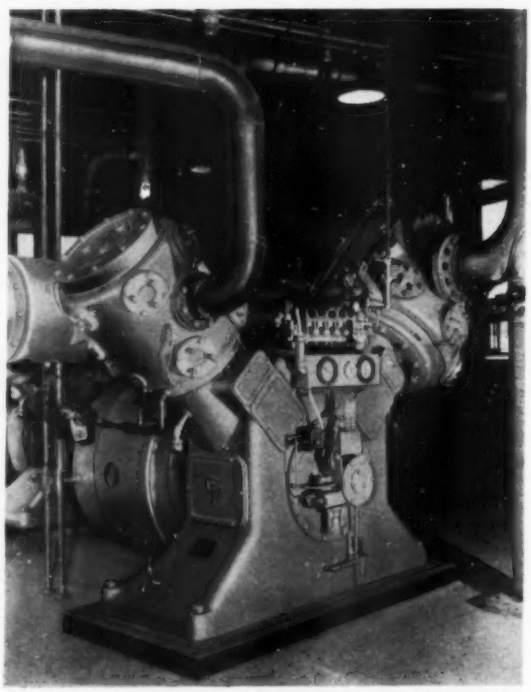
The ice tubes are delivered to a crusher, the duty of which is light because tubes of ice take much less power to crush than solid ice blocks. The ice fragments are then drained by passing over a wire-mesh conveyor and transferred to a rotating drum in which they are exposed to a blast of air at $-7°C$ and are undercooled to $-4°C$. Finally they are discharged to a storage bunker, from which they are transferred to the concrete batching plant as required by means of a screw conveyor. The bunker is a thin-walled sheet-steel tank within an insulating chamber, the cold air from the seven drying drums being circulated round the tank to prevent its receiving any radiation from outside. Care has been taken in the design of the drums, storage bunker and bunker outlets to prevent ice fragments from freezing together and to ensure smooth discharge.

A layout drawing of the Bhumiphol installation is given in Fig. 3. The entire plant has been built on the western bank of the Ping river, and a decentralised layout was chosen in order to reduce rock excavation on the steep slope. This involved running lengthy pipelines, most of which had to be insulated, but the cost was more than recovered by the saving in rock excavation. Fourteen compressors have been installed, each having a capacity of 320,000 kcal/h for water chilling and 162,000 kcal/h for ice making. It has been possible to use identical compressors for the two duties, with obvious benefit to flexibility and reduction of spare parts. These are six-cylinder machines; there is also a three-cylinder machine, with identical cylinder sizes, to provide the cold air for drying and undercooling the crushed ice.

Thirteen vertical condensers are placed near the engine room, seven for the ice machines and six for water chilling. A cooling tower has also been built on the hillside adjacent to the condensers.

Heavy-Duty Compressor Range

Consolidated Pneumatic Tool Co. Ltd. have introduced a range of heavy-duty stationary compressors having double-acting crosshead-type cylinders set at 90°. It is known as the Y class, and is available in seven sizes with outputs from 372 to 1,615 ft³/min at pressures from 80 to 125 lb/in², the horsepower range



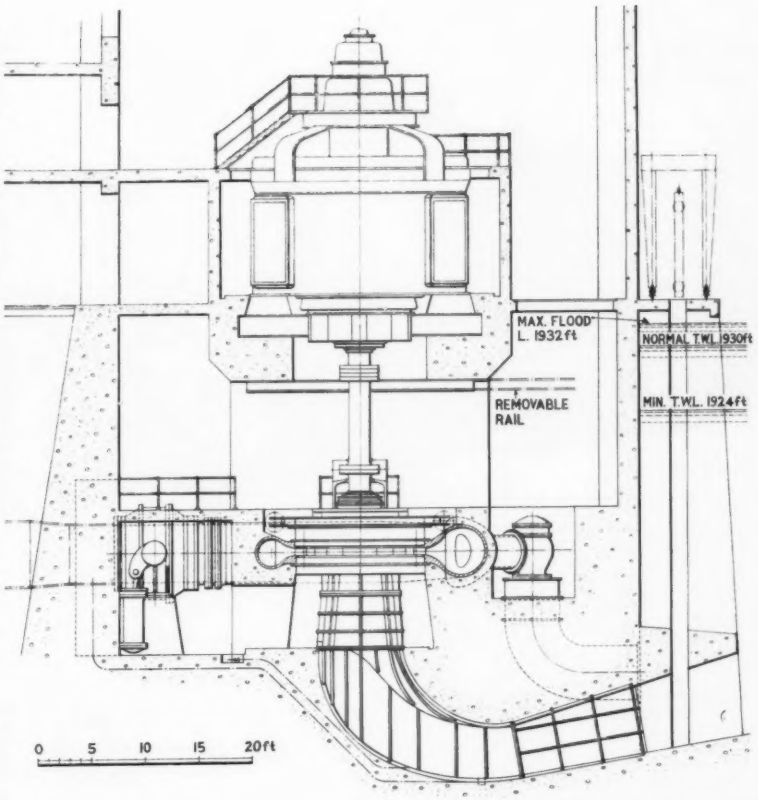
being from 75 to 300 b.h.p. Multistage units are available for pressures up to 3,000 lb/in². Drive can be effected by a flange-mounted motor, vee-belt drive, or a direct-coupled motor.

The frame, crankcase, and crosshead guides are an integral iron casting, and the cylinders are of Meehanite. The crankshaft is supported on three spherical roller bearings, the connecting-rod big-end bearings have split bronze-backed babbit-lined shells, and the crosshead-end bearings are of solid bronze. The first-stage piston is of aluminium alloy and the second-stage piston of cast iron, the weights being made equal to enable the moving parts to be balanced. Simplate disc-type valves are used. Forced lubrication is applied throughout, and the cylinders are water cooled. A shell-and-tube-type intercooler is located between the cylinders.

Maschinenfabrik B. Maier K.-G., of Brackwede, Westfalia, W. Germany, have sent us two brochures of a genuinely technical nature. One deals with hydraulic speed governors employed with pressure tanks, and the other with governors used without pressure tanks. These are useful and well illustrated publications that will be of general interest.

Turbines for Murray I

As recorded in the September issue of WATER POWER, the Snowy Mountains Hydro-Electric Authority in Australia are now to commence the second phase of development of their large hydro-electric power scheme. Geographically the programme is divided into two sections, the Snowy-Tumut and the Snowy-Murray areas. Both systems have a common major storage, the Eucumbene reservoir, which already serves the Tumut and Tumut II power stations. The next development is the Murray I power station which besides being the first power station in the Snowy-Murray section, will also be the largest station in the whole development.



Contracts have recently been placed for the generating plant for the Murray I power station, and Boving & Co. Ltd., London, through their Australian subsidiary company, secured the order for eight 130,000-h.p. vertical Francis turbines. These units will operate under a maximum gross head of 1,719 ft, which is one of the highest in the world for large Francis turbines, and it is believed that these units will actually be the largest Francis machines in the world operating under such a head. In addition to the turbines the contract includes eight 5 ft 4 in. diameter rotary valves of Boving design, and also a pressure-relief valve with each turbine.

The general arrangement of the plant is shown above. The turbine runners will be of cast stainless steel and because of the very high water velocity consequent on the high operating head, all waterways will require to be polished and all profiles carefully finished to close tolerances. The turbines are designed to run at 500 r.p.m., and the design head for best efficiency is 1,610 ft but the nominal output of 130,000 h.p. is to be achieved down to a net head of 1,510 ft. Under the maximum gross head envisaged of 1,719 ft the output will reach 160,000 h.p. and the generators are designed to utilise this output as an overload.

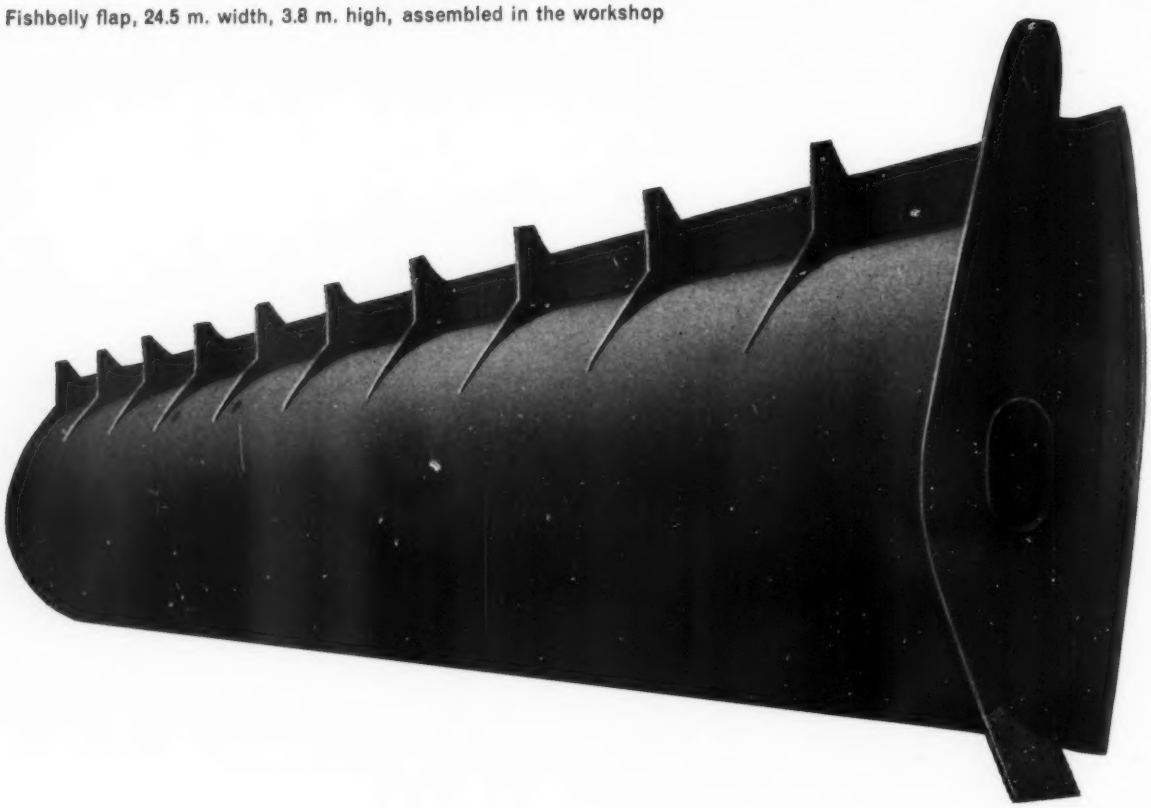
The contract for the generators, each having a nominal rating of 95 MW, has been placed with ASEA of Sweden and close collaboration between turbine and generator makers will be effective as it has been in many other recent Australian contracts, e.g. Barron Falls in Queensland and Catagunya in Tasmania. The manufacture of the turbines will be arranged partly in Australia and partly in England, where Markham & Co. Ltd., Chesterfield, will undertake the work to Boving designs and instructions. Markham are currently building for Boving an important proportion of the five Pelton turbines for the Poatina station, Tasmania, and the two Francis turbines for Barron Falls, Queensland, as well as other water turbines for Rhodesia, Spain and New Zealand.

Adcora Pervon Anticorrosive Coating

E. & F. Richardson Limited, Buckingham, have announced the addition to the Adcora range of anti-corrosive coatings of what they regard as an absolutely new approach to pitch-resin formulations. In 1957 Adcora A3 coal-tar/epoxy coating was first marketed and two years later was followed by Adcora A3 (SG). In an endeavour to improve the curing and adhesion of these products under adverse conditions, further work was instituted early in 1959, the outcome of which is Adcora Pervon. Generically, Adcora Pervon is a polyurethane pitch coating and is, so far as the manufacturer is aware, unique in the United Kingdom. Its range of usefulness is believed far to surpass that of epoxy-pitch coatings or, indeed, most straight epoxy products.

Adcora Pervon cures rapidly at all temperatures, even those below freezing point, and is unaffected by high humidity during the curing period. It can be

Fishbelly flap, 24.5 m. width, 3.8 m. high, assembled in the workshop



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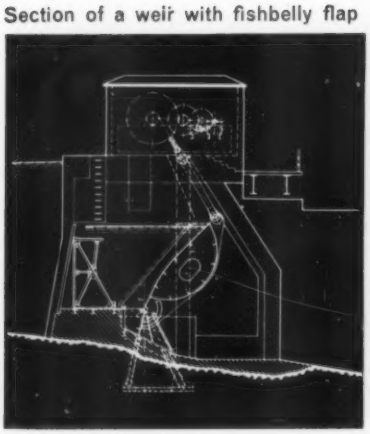

Fishbelly flap, inside view

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applied effectively both to blast-cleaned metallic surfaces and to those prepared by less-thorough methods. For continuous immersion, however, blast cleaning and a dry film thickness of 10 to 15 mils is recommended.

The chemical resistance of Adcora Pervon is described as exceptional. Ferrous surfaces protected with a 10-mil coating emerge unscathed after immersion for six months in 20% nitric or chromic acid.

To test the resistance of Adcora Pervon to prolonged immersion in water, specimens were placed in distilled water at ambient and elevated temperatures. We are informed that after 40 days' immersion, Adcora Pervon showed a water uptake as a percentage of the dry film weight of less than 1%. The best figures obtained in similar tests on obtainable coal-tar/epoxy coatings was 3% and with solventless epoxy coatings 4%. The appearance, cohesive and adhesive strength of Adcora Pervon was unaffected in any way by boiling distilled water.

Abstracts from the World Technical Press

Maintenance Work on Water Turbines

At the outset, particular stress is laid on the importance of effecting maintenance work on water turbines and their ancillary equipment in accordance with a prearranged schedule. Hints are then given on the organisation of the work, and two subsections deal in detail with the internal and external components of the turbine, especially those which are particularly subjected to wear and tear and to cavitation. Particular mention is made of the tests and checks required upon completion of the maintenance work. The first instalment of the paper ends with a few notes on spare parts and on the technological characteristics of the more frequently used materials. In the second instalment, the author deals in detail with the ancillary equipment under the following headings: Governors, safety devices to prevent runaway speed, braking systems, control valves, and automatic equipment. (A. Bonommo, *L'Energia Elettrica*, Vol. XXXVIII; No. 2, February 1961, p. 164, 16 pp.; No. 3, March 1961, p. 235, 8 pp.; 23 ff.)

Scour Sluices and Intakes

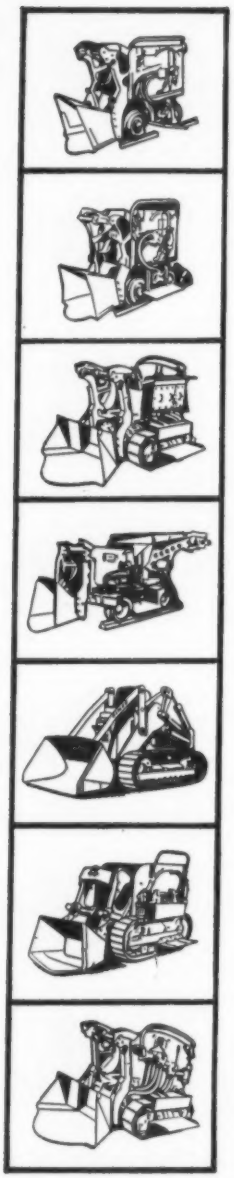
This paper was originally read at the Sixth Italian Conference on Hydraulics, and is on the subject of recent developments in scour sluices and intakes, with particular reference to very high arch dams, either thick or dome type, such as those at Vaiont (266 m), Mauvoisin (237 m), and Tignes (160 m). In view of the increase in dam heights, a careful study of their ancillary works, particularly scour sluices and intakes, was imperative, and examinations of the mechanical resistance and type of flow at these high heads were required. The paper first deals with the bottom gates controlling the dewatering of the reservoir, and emphasises the advantages of flat sliding gates, particularly the design developed by Società Calzoni, Bologna, and applied by Forges et Ateliers de Construction Electriques de Jeumont in several instances in Algeria and France. The arrangement most frequently adopted is the insertion into the transition section of the dewatering conduit of two identical gates 2 m apart. Aeration ducts are provided in the roof of the conduit: one just behind the downstream gate to admit air to the upper edge of the nappe outlet when dewatering is performed with partly open gates, and the other at the highest point of the conduit, to aerate the dome overhanging the free-flow level. Various installations of this pattern are described and discussed. This part of the paper concludes with a short note on other systems of control applied to dewatering conduits, such as needle valves, hollow-jet valves and others. The second part is devoted to intakes, with special reference to the installations at the Roselend and St. Guérin dams. Various other installations, most of them equipped with fixed-roller gates, are also described and discussed. (Dott. Ing. G. Lesi, French version by P. Dewawrin, *Revue Jeumont*, Vol. 53; No. 50, 1960/2, p. 75, 14 pp., 16 ff.; No. 51, 1960/3, p. 132, 16 pp., 8 ff.)

Hydro-Electric Generators

The following three papers were read at a recent meeting of the Swiss Association of Electrical Engineers held in Bern.

Paper No. 1 deals particularly with the special problems encountered in the case of synchronous generators either feeding long transmission lines at no load when running under steady-state operating conditions, or supplying a system that, in the case of slight exchanges of load, produces a surplus of reactive power. The first case results in the danger of self-excitation, and the second in instability. The use of a voltage regulator with good dynamic characteristics provides, to a certain extent, the means of maintaining operating conditions, which in the absence of such a regulator, would lead to self-excitation or endanger stability. This solution rules out the selection of uneconomic generators with smaller reactances, which are chosen simply to take into account the possibility of rare abnormal operating conditions. If it is required to achieve the full benefit of voltage regulators in this connection then the regulation system must be supplemented by special protective equipment. (W. Frey, *Bulletin de l'Association Suisse des Electriciens*, Vol. 52, No. 5 March 11, 1961, p. 149, 11 pp., 6 ff.)

Paper No. 2 is devoted to problems that, for various service reasons, frequently arise when HV transmission systems connected with hydro-electric power stations are operating at no load. These systems contribute substantial capacitances, which compel alternators to transmit capacitive currents. To this regime of capacitive power there corresponds a regime of underexcitation, and even negative excitation, in the alternator, if the capacitive reactance of the line is smaller than the synchronous longitudinal reactance of the alternator. This regime of negative excitation can be maintained in full stability without having to provide for overdimensioned alternators, provided that the alternators are equipped with convenient voltage regulators which can excite the machine negatively in the shortest time. However,



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stable running of the alternator is no longer possible in the case of too high a capacitance, as occurs, for instance, in lines of too great a length. This unstable regime, which may cause the alternator to fall out of step, occurs as soon as the capacitive resistance of the line is smaller than the synchronous transversal reactance of the alternator. Such a case of unstable running generally occurs when a long transmission line is switched off under load at the consumer's end. There are nevertheless appropriate systems of protection, which enable the alternator to be switched off prior to an occurrence of this type, but which allow for the full utilisation of the negative margin of the machine so as to ensure full stability of operation under the opposite conditions. (R. Comtat, *Bulletin de l'Association Suisse des Electriciens*, Vol. 52, March 11, 1961, pp. 152-155, 3 ff.)

In paper No. 3, special problems of on-load operation are considered that arise independently of frequency. Certain characteristics of electric load render purely hydraulic governing of generators very difficult. The difficulties occur particularly in instances of a single machine feeding a transmission system with a load that is independent of frequency. The author advocates the installation of an additional frequency regulator, so as to create a combined hydro-electric governing system ensuring not only stability of operation but also a quicker effect of the governing process (H. Schwendener, *Bulletin de l'Association Suisse des Electriciens*, Vol. 52, No. 5, March 11, 1961, pp. 155-157, 6 ff.)

Renovating Old Run-of-River Plants

The two plants described in this article are the Schwabenheim and Kochendorf stages of the Neckar River development, inaugurated in 1925 with about the same installed capacity. The generating equipment in each plant then consisted of three 2,800-h.p. vertical-shaft Francis turbines operating at 937 r.p.m. under a head of 8 m, and each driving through a spur-gear system with a ratio of 1 : 8, a 2,600-kVA generator on an upper open floor. Although these three-unit plants were able to operate at relatively favourable efficiencies, their total output was far below that of later Neckar plants equipped for the same rated discharge with only two Kaplan turbines. Investigations showed that it was possible to substitute Kaplan turbines direct coupled to generators, and to carry out economically the substitution of one set without having to stop the other units. A first new set was installed at both Schwabenheim and Kochendorf in 1956. The various phases of this operation, beginning with the erection of a 10-cm thick temporary wall, to protect the plant in use from demolition dust, are described in detail. The wicket gate of the old Schwabenheim turbine was still in good enough condition to be fitted to the new Kaplan turbine without any alteration to the concrete scroll, but a new wicket gate had to be built in at Kochendorf, as the old guide-vanes proved too low for the new Kaplan machine; it was also found impossible to keep the upper ring of the old Francis turbine. At both plants, the extensive civil-engineering work included the reconstruction of the concrete draft tube, which, in order to ensure better hydraulic conditions, was reduced in diameter, and the high oval cross section towards the outlet was altered to a relatively flat rectangular shape. The new generating sets were designed to allow the new stator to be placed on the floor of the power station, and be fitted on to the old ring of the gearing. Trials with the new generating sets showed such an improvement in efficiency that it was decided to repeat the procedure for a second set at Kochendorf; this set was put on the line in 1958, and the second set at Schwabenheim was due to be ordered about the end of 1960. (Dipl. Ing. Ernst Gamer, *Die Wasserwirtschaft*, Vol. 50, No. 10, October 1960, p. 253, 7 pp., 10 ff.)

NOTE: The above-mentioned journal also contains an article on "Large Control and Regulating Fittings in Water Engineering," by Dipl. Ing. Carl-Heinz Heym, pp. 266–271, 12 ff., as well as an account of the great flood in April 1959 on the Rio Negro in its Uruguayan reach, and the damage it caused to the Rincon del Bonete dam, power station and other works, by Dr. Ing. habil. Ferdinand Siemonsen, pp. 271–275, 13 ff.)

Developing the Turkish Euphrates-Tigris Basin

The well-planned large-scale development of Turkish water-power resources, initiated in 1950, is now proceeding with particular emphasis on the upper basin of the Euphrates and Tigris Rivers, which has a catchment area of 162,000 km² within the Turkish borders. The comprehensive scheme at present under consideration provides for the construction of 11 major dams, the key structure being the Keban dam, on which preparatory work has advanced sufficiently for construction work to begin. This article gives a description of the whole project, including the most important features of the annual storage reservoir planned near the small village of Keban, slightly downstream of the confluence of the Euphrates with its main tributary, the Murat. Economic and technical considerations favour a two-stage construction programme for the Keban concrete gravity dam, but the first stage alone is of such a magnitude that it could hardly be undertaken without foreign aid. The question that now arises is whether it would not be advisable to split the project into a greater number of smaller stages. As long as energy supply in the country grows faster than peak load, there does not seem to be any reason why the Turkish economy should be further burdened by new hydro-electric developments. In the north-western region alone, energy supplies exceeded the peak load by 120 MW in 1954 and 320 MW in 1960. An extension of the present distribution network will secure interconnected production while reducing local peak loads, and thus provide an increase of energy reserves. Either the output of the Keban dam installations would have to be transmitted to distances of over 1,000 km, or new major industrial centres would have to be created. At the present moment the Hazar power station near Elazig, barely 40 km distant from Keban, covers adequately the requirements of the only four large industrial concerns of the region; the possibility of substituting a simpler partial development for the comprehensive initial stage planned should therefore not be disregarded, as the problem of foreign credits for the purchase of equipment would not arise. The most urgent task that confronts the Turkish Government on the upper stretches of the Euphrates is flood control, and a reliable dam especially designed for this purpose is a definite necessity; an area of 6,175 million acres would be protected from flood dangers.

The urgency of an early solution of the problem is strongly emphasised by the author, who is of the opinion that a rational planning of the Keban dam on the lines he suggests would considerably improve the perspective of financial aid from abroad, as the execution of this initial stage of the scheme, on the reduced scale advocated, would also considerably benefit the downstream riparian countries, Syria and Iraq. The subsequent logical measures to be taken (irrigation system, closely meshed power grid, and the settling of new industries) could either follow immediately, or even in part precede the completion of this first stage. (Dr. Ing. Gerhard Rouvé, *Die Wasserwirtschaft*, Vol. 51, No. 6, June 1961, p. 141, 8 pp., 10 ff., 3 tables).

Gauging Flow by the Dilution Method

This paper gives an account of the application of the dilution method to flow measuring in connection with hydro-electric plants. Heretofore, difficulty had been encountered in applying the dilution method to the measurement of flows occurring in large low-head plants in obtaining a homogeneous mixture of a strength sufficient to procure accurate measurements. The effect of longitudinal in relation to transverse diffusion then becomes much more important than in more concentrated flows; indeed, in order to obtain an adequate homogeneous transverse diffusion by means of a simple injection appliance, the measurer must place himself at a distance from the injected section such that the longitudinal spreading of the saline cloud acquires a critical importance. This leads the authors to apply the procedure called the method of instantaneous injection, by integrating, as a function of time, the variation of relatively weak concentrations. In spite of the strong dilutions achieved under these conditions, the quantities of the dilution agent to be injected appear generally admissible at the scale of the problem tackled, and it will perhaps be possible to reduce them by improving still further the sensitiveness of the methods of compared analysis. The tests described applied to the Rabodange plant for high and medium heads, and to Echarcon and Argentat for high heads. (Wolf & Pérez, *Mémoires et Travaux de la Société Hydrotechnique de France*, Vol. 1, 1961, p. 72; *La Houille Blanche*, Vol. 16, No. A, July 1961, p. 412; 6 pp., 3 ff.)

Translatorv Waves in Power Canals

The power canal instanced is the 7-km headrace of the Zevio plant, which has now been over a year in service on the Adige River, downstream of Verona, and is designed for a maximum discharge of 150 m³/sec. The authors of this paper first give an account of the computation procedure adopted at the designing stage of the project for determining the perturbative waves occurring at starting-up or shutting-down periods and when stopping the power flow in full or in part. The canal, in fact, was built on the basis of the results arrived at by computation, which are compared with those of the practical tests carried out on the plant shortly after it had been put into service. The testing equipment installed in the headrace for measuring the wave phenomena consisted of seven floater-type hydrometrographs; in addition, two cinematographic recording stations had been set up to obtain the geometric characteristics of the wave. The tests established that, slightly upstream of the power house, the waves lose their character of a stiff-stepped flat surge, and split up into a series of undulations practically equal in length. While, on the one hand, the average height of wave recorded is in fair agreement with the computed results, on the other hand the presence of undulations considerably increases fluctuations which, in some positions, reach twice the average values. (G. Benini, A. Vecellio, F. Casara, *L'Energia Elettrica*, Vol. XXXVIII, No. 7, July 1961, p. 620, 13 pp., 13 ff.)

Shikmen Project

The first large-scale water resources development on Formosa, supported by US funds and engineering, is beginning to take shape in the area south-west of Taipei. It is primarily designed as an irrigation project vital to the expansion of food production, but involves the construction of a reservoir three miles wide and ten miles long, and will include a 436-ft high rockfill dam, a power station housing two 45-MW generating units, a spillway, and a 17-mile canal system that ensures water supply for a wide area. The power installation is expected to be completed by 1963, and will provide for industrial and residential needs. The Morrison-Knudsen-International-Construction Company is directing construction. (*Power Engineering*, June 1961, p. 53, 1 f.)

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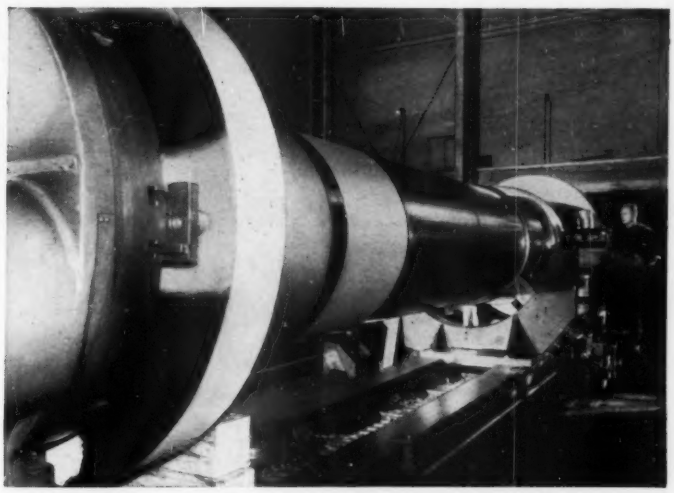

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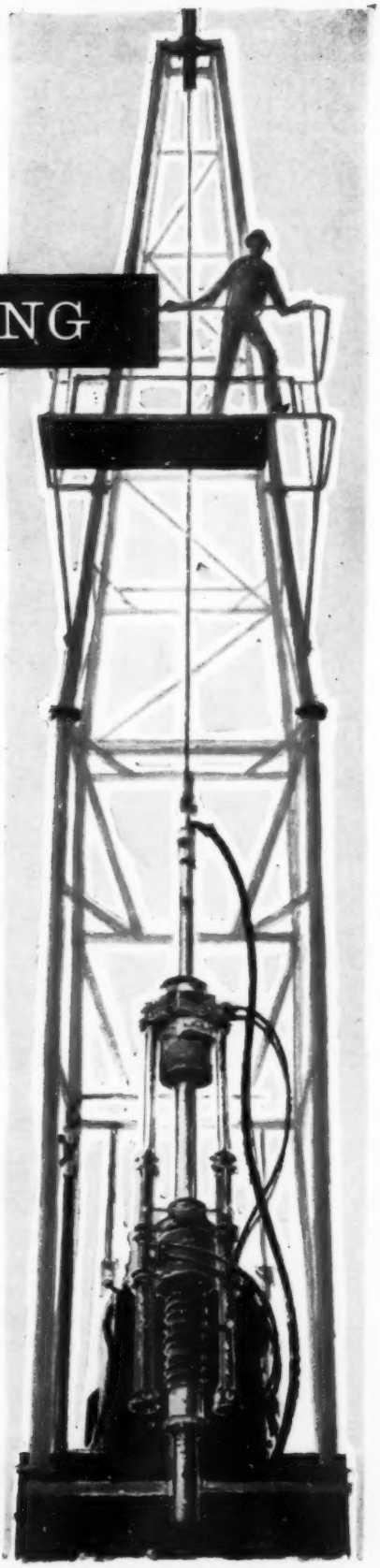

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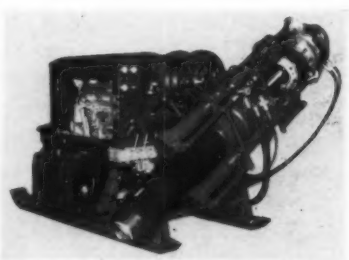

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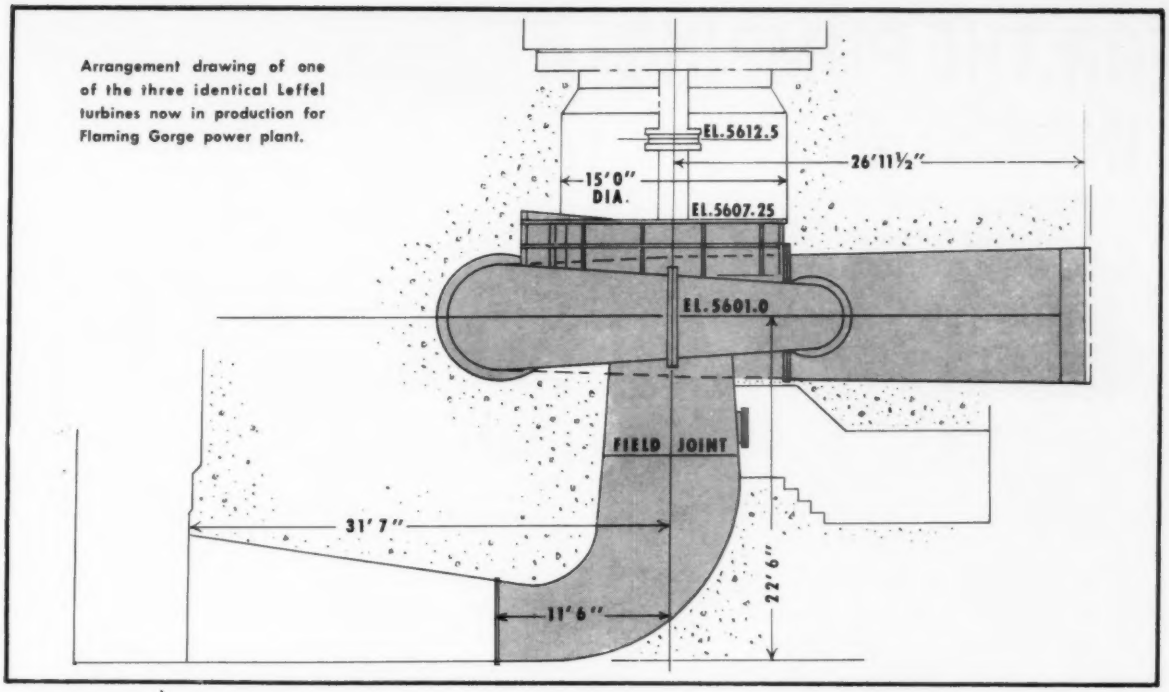

Arrangement drawing of one of the three identical Leffel turbines now in production for Flaming Gorge power plant.

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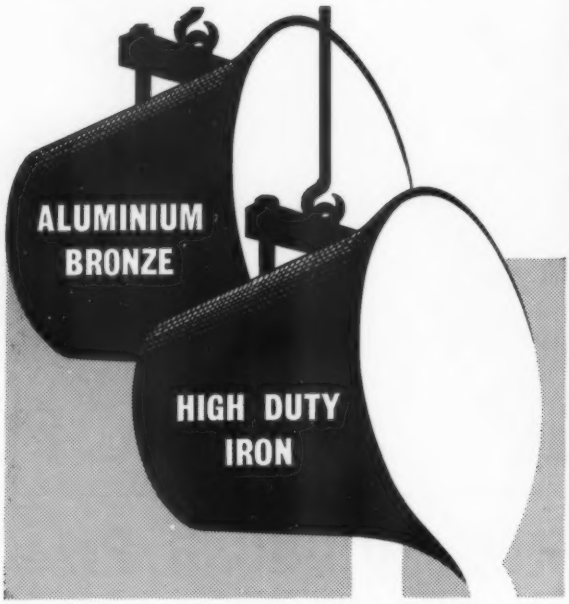

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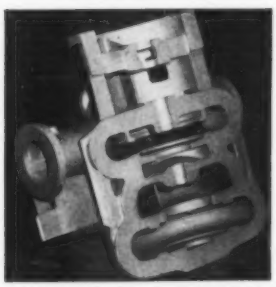

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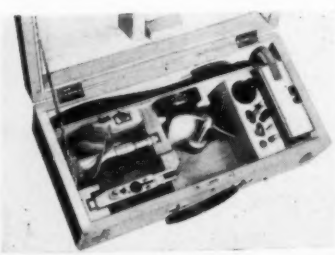

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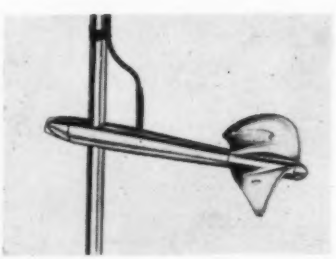

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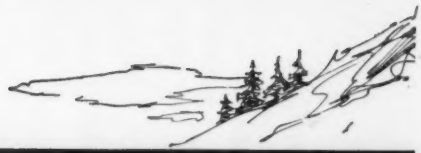

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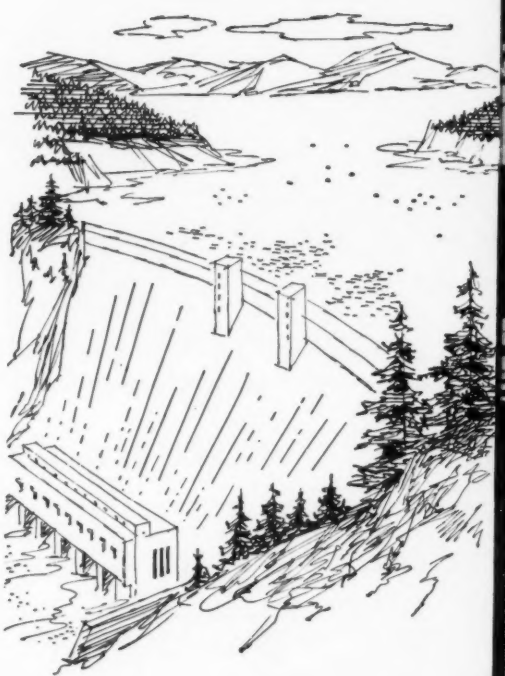

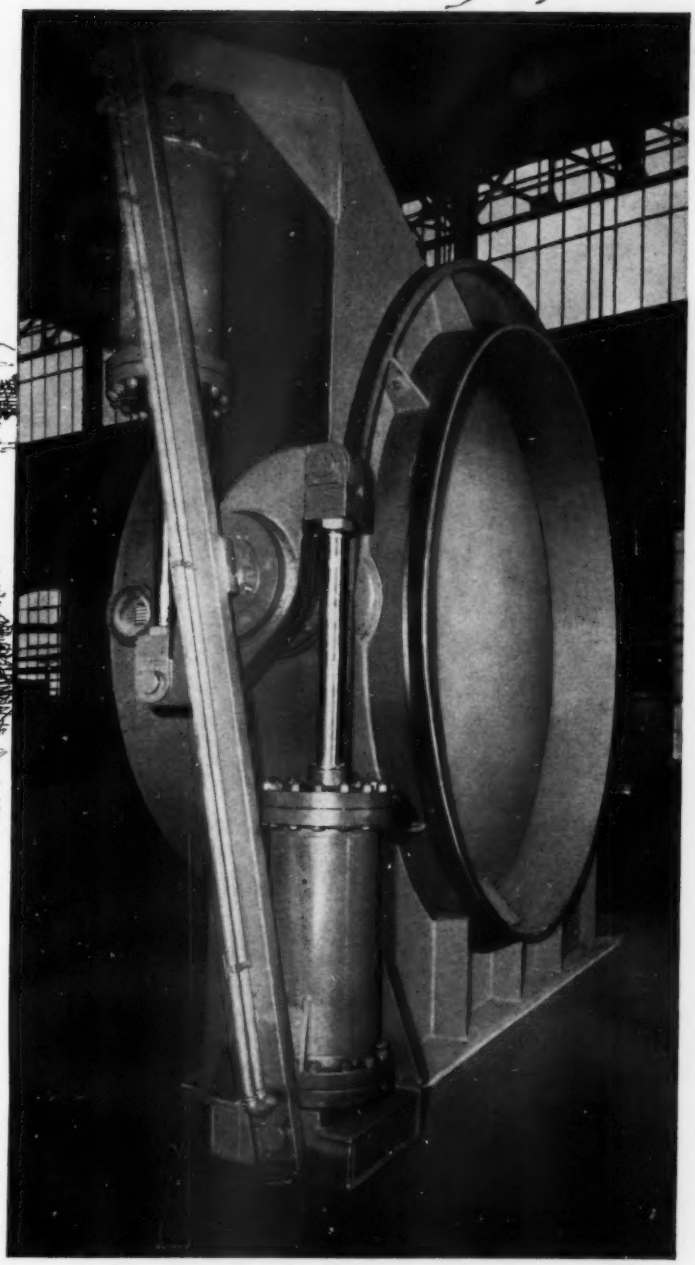

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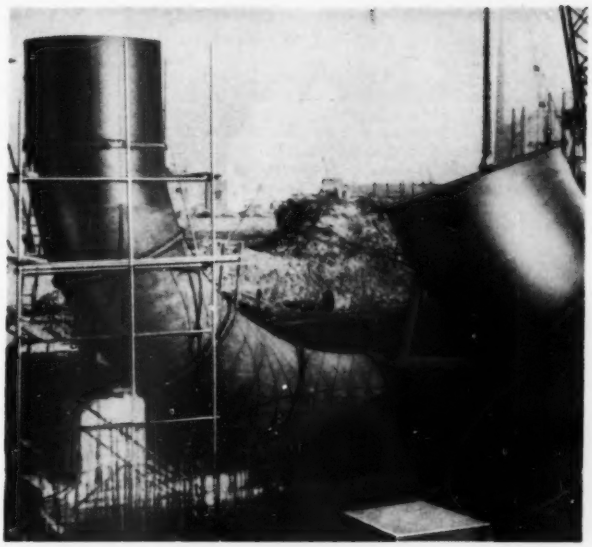

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INDEX TO ADVERTISEMENTS

A

Acciaieria E Tubificio Di Brescia 38
ACEC 6
Allgemeine Elektricitäts-Gesellschaft ... ... —
Alimark Verken, A.B. ... ... —
Allis-Chalmers Hydraulic Division 25
Allmanna-Svenska Electriska Aktiebolaget 39
Ansaldo San Giorgio, S.p.A. 9
Armfield Hydraulic Engineering Co. Ltd., The ... —
Associated Electrical Industries (Instrumentation) Division .... —
Associated Electrical Industries (Manchester) Ltd. 10 & 11
Associated Electrical Industries (Rugby) Ltd. 10 & 11
Associated Electrical Industries (Woolwich) Ltd. —
Ateliers de Constructions Electriques de Della ... —
Atlas Copco A.B. ... ... —

B

Balfour, Beatty & Co. Ltd. 58
Bell, Theodore & Co. Ltd. ... ... Outside Back Cover
Birkett, T. M., Billington & Newton Ltd. 56
Bochumer Verein ... ... —
Bouchayer & Viallet ... ... —
Boving & Co. Ltd. 5
Boyles Bros. Drilling Co. Ltd. 54
British Insulated Callender's Cables Ltd. ... ... —
British Ropeway Engineering Co. Ltd. ... ... —
Brown, Boveri & Co. Ltd. 45
Bruce, Peebles & Co. Ltd. ... ... —
Bucyrus-Erie Co. Ltd. ... ... —
Buss, A.G. ... ... —
Butters Bros. & Co. Ltd. ... ... —

C

Canadian General Electric Co. Ltd. ... ... —
Canadian Vickers Ltd. 57
Canadian Wood Pipe & Tanks Ltd. ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. ... ... —
Charmilles Engineering Works Ltd. 37
Cockburns Ltd. 32
Compagnie Industrielle de Travaux 14
Consett Iron Co. Ltd. 21
Consolidated Pneumatic Tool Co. Ltd. ... ... —
Costruzioni Generali Farsura Cogefar, S.p.A. ... 23

D

de Roll, Louis, Ironworks Ltd. 3
Dominion Engineering Co. Ltd. 53
Doulton Industrial Porcelains Ltd. ... ... —
Drees & Co., G.m.b.H. 36

E

Eimco (Great Britain) Ltd. 52
ELIN, A.G. ... ... —
Elliott Bros. ... ... —
English Electric Co. Ltd. ... ... Front Cover
English Steel Forge & Engineering Corporation Ltd. 24
Escher Wyss Ltd. ... ... —
Expandite Ltd. ... ... —

F

Ferranti Ltd. ... ... —
Ferrum Montage ... ... —
Fischer, Ltd., George ... ... —

G

Galileo Officine di Battaglia Terme 31
General Electric Co. Ltd. ... ... —
Gilbert Gilkes & Gordon Ltd. ... ... —
Giovanola Freres, S.A. ... ... —
Glenfield & Kennedy Ltd. 28
Gordon Valves, J., Ltd. ... ... —
Government of Ghana ... ... —

H

Harland Engineering Co. Ltd., The ... ... —
Hartley (Stoke-on-Trent) Ltd. ... ... —
Henderson, John M. & Co. Ltd. ... ... —
Hitachi Ltd. ... ... 15 & 34
Huhn, G. 58
Hydraulics & Pneumatics Ltd. ... ... —
Hydraulic Service & Equipment Co. Ltd. ... ... —

I

Impresit Girola Lodigiani S.P.A. 46
INGFA 56
International Engineering Co. Inc. ... ... —
International General Electric Co. ... ... —

J

Jonneret, S.A. Ateliers de Construction ... ... —

K

Karlstads Mekaniska Werkstad, Akt. ... 42 & 43
Krupp, Fried. Maschinen- und Stahlbau 51
Kuljian Corporation, The 18
Kvaerner Brug A.S. 35

L

Leffel, James & Company, The 55
Lepper Transformatorenwerk August ... ... —
Le Materiel Electrique, S-W 14
Limi Torque Valve Controls Ltd. 7

M

Magrini, S.p.A. ... ... —
Maschinenfabrik Augsburg-Nürnberg, A.G. 13
Maier, B., K.G. ... ... —
Mechans Ltd. 59
Micanite & Insulators Co. Ltd., The 12
Michell Bearings Ltd. ... ... —
Mitchell Construction Co., The 41
Mitsubishi Electric Manufacturing Co. 40

N

Neyrpic ... ... 16 & 59
Nippon Gaishi Kaisha Ltd. 4
Nuttall, E., Son & Co. (London) Ltd. ... ... —
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company ... ... —
Ossberger Turbinenfabrik ... ... —

P

Pellizari A., & Figli, S.p.A. 47
Pirelli-General Cable Works Ltd. ... ... —

R

Ransomes & Rapier Ltd. 17
Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Rheinstahl Union Brückenbau, AG. ... ... —
Riva Costruzioni Meccaniche 8
Rosenthal Isolatoren, G.m.b.H. ... ... —
Ruston Bucyrus Ltd. ... ... —

S

S.A. Ateliers De Secheron ... ... —
Sakai Iron Works Co. Ltd. 33
Salvi, A. & Co. ... ... —
Salzgitter Maschinen Aktiengesellschaft ... ... —
Savoisienne ... ... —
Scarpa & Magnano ... ... —
Siemens-Schuckertwerke, A.G. 48
Smail, Sons & Co. Ltd. 56
Smith, Fredk. & Co. ... ... —
Sprecher & Schuh Ltd. ... ... —
Soc. p. Az. Cementi Armati Ing. Mantelli ... ... —
Societa Nazionale Delle Officine Di Savigliano ... —
Societe des Forges et Ateliers Du Creusot 14
South Durham Steel & Iron Co. Ltd. ... ... —
South Wales Switchgear Ltd. ... ... —
Steatite & Porcelain Products Ltd. 44
Sulzer Bros. (London) Ltd. 50
Svenska Metallverken, A/B 29

T

Tampella OY ... ... —
Technoexport ... ... —
Tees Side Bridge & Engineering Works Ltd. ... —
Terni Per L'Industria E L'Elettricita 19
Tokyo Shibaura Electric Co. Ltd. ... ... —
Torno, Giuseppe & Co. ... ... —
Tosi, Franco, S.p.A. ... ... —

V

Vereinigte Osterreichische Eisen- und Stahlwerke 26 & 27
Vevey Engineering Works Ltd. 20
Victor Products Ltd. ... ... —
Voith, J. M., G.m.b.H. 30

W

Waagner Biro, A.G. ... ... Inside Back Cover
White, R. & Sons (Engineers) Ltd. ... ... —
Wood, Hugh & Co. Ltd. 22
Woodward Governor Co. ... ... —

Y

Yorkshire Electric Transformer Co. Ltd. ... ... —

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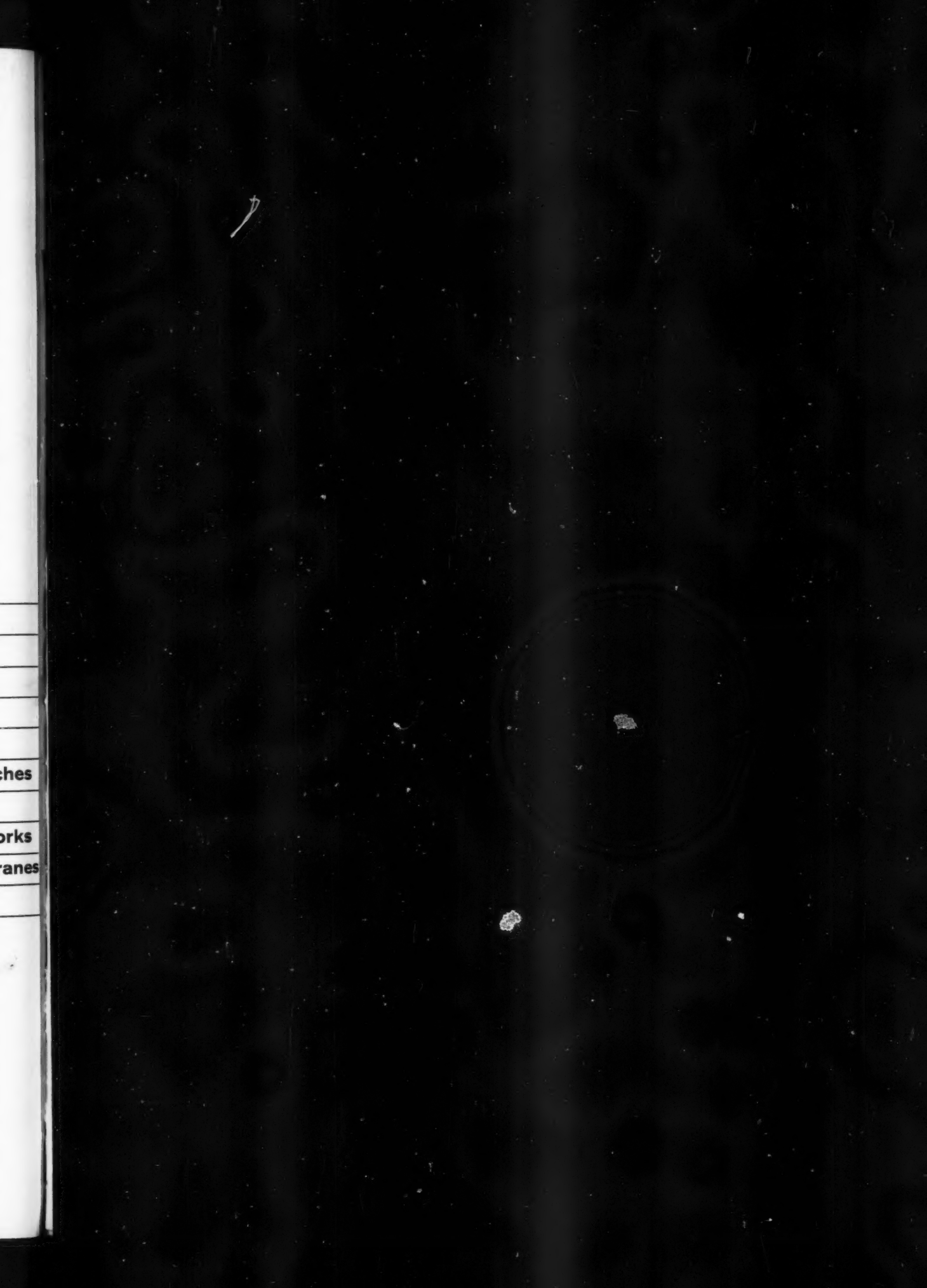
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